REVERSE AUCTION BIDDING-BID TIME INTERVALS ANALYSIS

A Thesis

by

MENGYAN XIAO

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Chair of Committee,	John M. Nichols
Committee Members,	Edelmiro Escamilla
	Kevin T. Glowacki
Head of Department,	Joseph P. Horlen

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ABSTRACT

Reverse Auction Bidding is for the purchase of goods or services that has developed in line with the development of the World Wide Web. A number of agencies utilize Reverse Auction Bidding as their procurement tool. In an RAB, human bidders bid against each other by reduce their bid price.

It is believed the computer bidder machine can be introduced into reverse auction bidding to compete against human beings. However, the reaction time of a computer machine is much faster than a human. This research is looking to develop the algorithm for the computer machine to follow, so that when the computer is bidding against a human being, people cannot determine that it is a machine bidding in the game.

This research is the 26th case study of Reverse Auction Bidding in Texas A&M University, Construction Science department. The research has analyzed the existing data which collected from previous RAB experiments. The results show two rules can be setup for computer bidder machines. Rule 1, when the computer is bidding during the segment 1 of each section, it shall randomly select from 2 seconds to 23 seconds as its time-intervals. Rule 2, when the computer is bidding during the segment 2 of each section, it shall randomly select from 2 seconds to 9 seconds as its time-intervals.

DEDICATION

To my father and mother.

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NOMENCLATURE

RAB	Reverse Auction Bidding
KTS	Keirsey Temperament Sorter
ASP	Application Service Provider
SQL	Sequential Query Language
TAMU	Texas A & M University

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION

Background

Reverse Auction Bidding is for the purchase of goods or services that has developed in line with the development of the World Wide Web. The system relies on a central server and database being used to accept bids for the required contracts. A number of private agencies and governments now require Reverse Auction Bidding (RAB) as their procurement methods in construction projects (Yuan, 2013). However, there are still many challenges for some is using (Angelo, 2002; Caniëls & van Raaij, 2009). These challenges are whether or not RAB is economically efficient, whether the system is akin to bid shopping and is the system inherently fair to both sides of the contract.

The traditional bidding method, such as closed sealed bid, allows the bidders to submit their prices only once during the bidding time, where RAB has multiple bids for a single contract. RAB uses an online tool that enables the bidders to lower their prices several times during the bidding period, the lowest bidder would be awarded the bid (Angelo, 2002). Human bidders compete against each other. The bidder may lower an existing bid from another player.

Human bidders are relatively slow when compared to a computer, there is the same ratio between a second and a nanosecond as there is between 31 years and a second. Computers can look at many aspects of bidding in the time a human player can merely read the current bids. This has resulted in the phenomenal known as flash trading on the stock market (Hasbrouck & Saar, 2013; Manahov, Hudson, & Gebka, 2014).

Problem Statement

The research will seek and identify the statistical properties of time-intervals of human bidders in Reverse Auction Bidding to plan the algorithm of a computer bidder machine in Reverse Auction Bidding.

Research Questions

The intent of the research is to seek the properties of a computer algorithm that does not appear to be a computer based procedure, but plays at human time rate. The relevant questions are:

i. What are the time-intervals between bids and patterns for a human bidder?

ii. How to establish the time intervals for a computer bidder so that the human bidders do not realize that they are competing against a machine instead of human?

iii. What algorithm will the computer machine follow?

Significance of the Study

The bid time intervals for a computer bidder machine can be established based on the result of this study. In addition, human bidders' reactions when competing against the machine can be analyzed in further studies. To construct a computer bidder machine without making other human bidders realize that they are competing to a machine will be the optimal goal of this serial of research. Thus, this research helps to further understand human bidders' behavior in Reverse Auction Bids, which enables introduce a human intelligence program into RAB transactions.

Delimitations

i. The study is limited to the Department of Construction Science, Texas A&M University. The scope of participants is limited to graduate students of the Construction Science Department.

ii. A controlled experiment by other research people in the Construction Science Department.

iii. The study ignores all clerical mistakes of the bidders. For example, mis-input a number or a digit when entering a bid.

iv. The reverse auction experiment was carried out in a stable economic situation, and there was no other factors influence the bidder's decisions.

CHAPTER II

LITERATURE REVIEW

Introduction

Since Reverse Auction Bidding is been utilized in the industrial world from 1990s, a lot of research and studies have been conducted. However, arguments and acceptance of Reverse Auction Bidding are ongoing. Researchers have paid a lot of attention to the characteristics of Reverse Auction Bidding itself. However, less research has been done on the bidders' behavior and performance in RAB.

This chapter outlines a summary of:

- Definitions
- English Auction
- Dutch Auction
- Sealed First Proposal Auction
- Vickrey Auction
- Reverse Auction
- Reverse Auction Bidding Procedures
- Buyers and Purchasers' Relationship
- Human Intelligent Computer Program in Financial Trades
- Previous Studies of RAB in Texas A&M University
- Personality Test
- The Review of RAB system in TAMU

Definitions

λ player	This represents the bidder group, treated as a single entity for the purpose of game analysis.
λ_i player	The ith bidder in the bidding group.
υ player	This represents the purchaser.
α game	The postulated sub-game played between bidders in seeking economic advantage over the remaining bidders. This game almost always disadvantages the υ player, but the υ player created the system and so is responsible for the υ player's economic losses as a result.
ω game	The postulated sub-game played within the Reverse Auction Bidding game between the purchaser and the bidders. In terms of this analysis, it is deemed to effectively reduce to a two-player game, with competition implications for all players. The υ player in reality sees only the average of all won bids.
τ	Bid time allowed for each round of play in the game.
δ	Period between bid time τ that represents the work time in the game.

B_j	ith bid
B_v	Accepted bid for each job.
K	This variable is a fixed dollar sum, representing the υ player's base price, although in this game K is a vector of costs.
Γ	This variable is a fixed dollar sum, representing the υ player's maximum incremental price above K.
Ξ	This variable is normally defined by the set of numbers $\{\Xi \mid 0 < \Xi \leq 1\}$, although negative values of Ξ are permitted by the Reverse Auction Bidding system. Ξ is used to normalize the profit data. A negative Ξj represents a loss on direct costs to the λi player who makes this type of bid, and enough of these bids will lead to a bankrupt player. This type of play is discouraged as the assumption in the game is steady state economic conditions in the outside economy. Future studies may look at a failing market, but that is beyond this study.

Aggressive Bidder:	Willing to accept calculated risk of greater than average loss in pursuit of greater than average returns, first defined by Chouhan (2009).
Bid:	A single entry into the game that represents a legally acceptable offer to complete the work assuming the bidder has been prequalified.
Bidder:	An entity that submits a bid. In this game, there are usually three to ten bidders, and each is an individual, rather than a company. In van Vleet's (2004) study, none of the bidders had prior experience, which is not true for Chouhan's (2009) study.
Bid Efficiency:	Is the ratio of the total number of jobs won to the total number of bids. This is one of the postulated metrics for determining success in the α game.
Case Study:	'Designed to study intensely one set (or unit) of something; for e.g. programs, cities, counties, worksites- as a distinct whole, with the goal of understanding the set as a distinct whole in its particular context. A case study reveals the process and outcome at certain sites and the way in which these interrelate. Case studies are

	conducted primarily using qualitative techniques, but do not exclude quantitative data (van Vleet 2004)'.
Dutch Auction:	is a type of auction where the auctioneer begins with a high asking price which is lowered until some participant is willing to accept the auctioneer's price, or a predetermined reserve price (the seller's minimum acceptable price) is reached (van Vleet 2004).
Efficiency:	The ratio of the output to the input of any system.
Game:	A series of jobs for the construction of a reinforced concrete floor slab, each game lasts approximately 8 to 10 weeks in game play time, with each round of the game modeling a week and occurring in a 20 minute period, with 15 minutes of bid time and 5 minutes of build time.
Game theory:	A formal analysis of conflict and cooperation among intelligent and rational decision makers.
Job:	A work unit, in this case a reinforced concrete slab for a home builder, taking 5 working days to construct.

Loan amount:	It is a bank loan or a guarantee taken by the bidder with the purpose of increasing the bidders' job capacity. The cost is $500 per job.
Loss:	Negative return applied to a business undertaking after all operating expenses have been met.
Profit:	The return received on a business undertaking after all operating expenses have been met.
Reverse Auction Bidding:	It is a single or multiple-item, open, descending-price auction. The initiator specifies the opening bid price and bid decrement. Each bidder submits a successively lower bid. At the end of the auction, the bidder with lowest bid value is being considered as a winner (van Vleet 2004).
Sealed Bidding:	In this type of auction, all bidders simultaneously submit bids in such a way that no bidder knows the bid of any other participant. The highest/lowest bidder is awarded the contract at an agreed price, all other things being equal .(van Vleet 2004).
Traditional bidding:	In this type of auction all bidders simultaneously submit bids in such a way that no bidder knows the bid of any

other participant. The highest/lowest bidder is assumed to be awarded at the price submitted provided no other contracts opened on the decision process (Chaudary 2009).

Winners Curse: Problem faced by uninformed bidders or poor game players. For example, in an initial public offering uninformed participants are likely to purchase larger allotments of issues that informed participants know are overpriced.

Game Type:

Consider a Reverse Auction Bidding game where the υ player is willing to accept bids of the type shown in equation (1):

$$B_j = \mathrm{K} + \Xi_j \, \Gamma, \tag{1}$$

Γ represents the upper limit the υ player is prepared to pay in the game above the nominal minimum bid amount K. A negative Ξj represents a loss on direct costs to the λi player who makes this type of bid, and enough of these bids will lead to a bankrupt player (Guhya 2010). The concept of Γ can be attributed to Feigenbaum (Nichols 2010), who considered there had to be an upper limit everyone was prepared to pay for a service or good, the so called price point of economic theory.

The bidding period for each game lasts for a set time, τ, in this case it is 15 minutes. The total cost for υ player is shown in equation (2):

$$B_v = \sum_{j=1}^{n} B_j, \quad (2)$$

This total cost is based on the accepted lowest bid for each job, where the λ_i player submitted a valid bid for a job. Each λ_i player then has a unique set of bids and a unique set of jobs, with a total return to the λ_i player defined by a simple summation (Guhya 2010). In terms of the υ player, the average cost per job and the total cost are the main elements. The lowest and highest costs are of interest, but the υ player's clear objective must be to lower the average price. This is not necessarily the key objective of the other players.

English Auction

English Auction was known as candle auction which becomes popular in 17th century in England. Candle auction sets up its period based on the expiration of a candle flame all the participants do not know the exact auction period. The candle auction helps eliminates the auction spinning, because nobody knows exactly when the auction will ends, which helps to eliminate the spinners to enter into the auction in the last seconds. However, it went out of favor in 18th century.

An English Auction is the traditional type of auction that sells scarce goods or services. For example, artwork or antiques. Different from rouge materials, in name of concrete, woods, steels, that can duplicate in a short time and a great quantity. The scarce goods are unique from others. Even to reproduce an antique becomes technically possible now days, the value of a duplicated product is less than the real one. English auction is derived from the economic characters of scarce goods.

In the English Auctions, the buyers are competing against each other by rising their bid prices. The bid prices will increase until only one bidder remains in a given time frame. Whether bids are submitted online or call their prices, the transparent auction process makes the buyers know current highest price. So that they can choose to raise their prices or remain the same with the changes of their bidding strategy.

At the end of English Auction, the auctioneer will announce the winner who provides the highest price in a given time frame.

Dutch Auction

Dutch auction was first adopted in Dutch tulip market in 16th century, when the tulip price was extremely high. Because the long growing period of tulip makes it hard to meet the high demand of the market, in addition, tulip can be traded in the market for only three months. The sellers will sign the contract with tulip purchasers during the year to deliver the flower in a given time.

In order to achieve as many benefits as possible, the tulip sellers have set up the rules of an auction. The seller will announce an artificial high price where nobody wants to buy the product; she will reduce her prices constantly until the first buyer accepts the price and the auction end at the point. The Dutch auction will be terminated in a fast pace. It is beneficial for both purchasers and sellers since it is very hard to predict the real price of the tulip, where the demand meets supply. The tulip sellers can sell their flowers immediately without considering their contract been canceled. Simultaneously, the purchaser can buy tulip at the price, which is acceptable to them. The Dutch auction still is a powerful tool for purchasers to procure bulk amount of goods.

Sealed First-Price Auction

Sealed first-price auction is different from the English Auction that allows all the bidders to submit their bid price only once. Before the bid opening, bidders do not know other competitors' bid price. As this auction does not allow the bidders to disclose their prices, the bidders cannot adjust their prices accordingly (McAfee, Dinesh Satam, 1987). The bid will be awarded to the one who provide the highest price (Krishna 2002).

Three uncertainty conditions may result to the winner's curse in sealed first-price auction. (Warren J.2009) Firstly, the bidders may have a poor understanding of the information that they receive. Secondly, bidders may interpret in the auction requirement differently. Thirdly, the evaluation of the product is subjective and uncertain. The winning bidder is the one who provide the highest price. However, this price may exceed the true value of the product. This situation results in a cursed winner.

It is suggested there are some implications for the bidder. For example, the bidders could be less aggressive in an auction, and they should know as much about the contract requirement as they can collect so that a more accurate price can be estimated before they enter into the auction. In addition, do not bid when the true value of the product is not fully known.

The sealed first bid auction is popular among the government mining contracts. It is also been utilized in some of the UK construction projects. (Shu Yuan 2013).

Vickrey Auction

Firstly described by William Vickrey, the professor in Columbia University in 1961, (Vickrey Wulliam, 1961). Vickrey Auction is a type of auction that the bidders

submit their written bid without known other bidders' prices. The highest bidder will win the auction, but she only pays the second-highest bid price.

Vickrey Auction is similar to an English Auction, but by awarded the contract to the second-highest bidder, the bidders are encouraged to provide the true value in an auction. Vickrey Auction has been studied in the literature, but not many Vickrey Auction are been done in the real world practice. Google and Yahoo!'s online advertisement programs have utilized Vickrey Auction. (Hal R. Varian, 2006)

Compared to a traditional English Auction, the drawbacks of Vickrey auction are obvious. Firstly, the Vickrey Auction does not allow the bidders to explore the true value of goods by observe other bidders' prices. Secondly, sellers may intend to bid a higher price to increase the profit. Thirdly, it is vulnerable to bidder collusion, even bidder collusion is a problem for all types of auctions, and the bidders can lower their price, by revealing their bids to each other in Vickrey Auction.

Reverse Auction

Reverse Auction bidding is a type of process where the buyers and sellers roles are reversed. In the traditional type of auction, buyers compete to achieve goods by increasing their prices. In a reverse auction, the sellers compete to obtain the business by lowering their prices.

Reverse auction is also known as Procurement auction, e-auction, sourcing event or B2B auction. It is mostly used in government procurement.

Reverse Auction Bidding Procedures

Reverse Auction Bidding is an e-commerce transaction. An online trusted third party is essential, which provides a platform for the purchasers and sellers to conduct their businesses (Srinath, Samrat, & Mamata J., 2011). Different from sealed bidding process, the bidders can know the ranks of their prices and decide whether to bid a lower price or remain the same. Bidders can reduce their prices during the entire period of bidding time. In successful reverse auction bidding, 5 phases are required (see Figure 1)

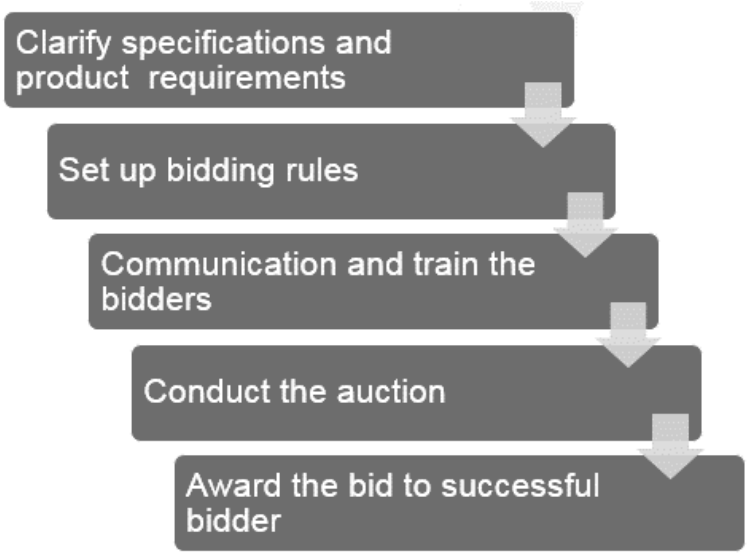


Figure 1 Reverse Auction Bidding Procedure

The first phase is that purchasers have to clarify the specifications and requirements of products and services, as they need. Similarly, to a sealed bidding process, the purchasers have to provide drawings and specifications of works or descriptions of the materials they want to buy. The cleaner the description provided by

the purchaser, the more likely a reverse auction bidding is going be successful (Srinath et al., 2011).

The second phase is that purchasers have to find a third trusted party who provides the service for purchasers and sellers to create the bidding rules. Purchasers can pre-select the bidders based on bidders' previous performance, the qualities of products, reputations and their capacities to provide products and services. Carefully evaluate the bidder's qualification and set up the bidding rules is important for both the purchasers and bidders to eliminate economic loss in reverse auction bidding.

Communicate with and train the bidders is the third phase of the auction. Purchasers need to be sure that the bidders understand how to access the screen and know how to conduct the bidding in the system. In addition, the purchaser can reduce the potential economic loss by given a good training program to the sellers. A good training program ensures the sellers understand the bidding rules which are established by the purchaser before conduct RAB.

The fourth phase is to conduct the auction. The bidders run the auction for a certain period, prices or the rank of bidders will be provided to every participant.

The last phase is to award the bid to the successful bidder. Bids do not necessarily always need to be awarded to the lowest bidder. The purchaser can make the decision that to finalize the bid to which bidder based on multi-attribute evaluations of the participants. However, the transaction needs to be terminated after the bid closing time.

There is an intense debate about utilizing Reverse Auction Bidding in the construction industry. Some argue that reverse auction bidding is nothing more than "bid-shopping". In addition, the objectors advocate that reverse auction bidding could reduce the quality of products and leave negative impacts of buyer-supplier relationships (Angelo, 2002). Further, there is no evidence to indicate the prices have been dramatically reduced by adopting reverse auction bidding in construction projects (Guhya, 2010).

To compare the reverse auction bidding price of a contract with the contract that is awarded by sealed-bidding process is impossible (Guhya, 2010).

Buyers and Purchasers' Relationship

Transactions are categorized as transactional exchange and relational exchange. (Daly, Sp, 2005). The transactional exchange is a type of business where the buyers and suppliers only pursue profits but do not try to establish a long-term relationship with each other. To the contrary, the relational exchange considers a long-term corporation between buyers and sellers as an important factor in doing business. It is believed Reverse Auction Bidding is a transactional exchange, where the price is the only critical factor. In this situation, buyers rarely consider suppliers as their strategic partners.

In addition, Manoochehri claims that once the main goal of buyers is to focus on price reduction, the strategic relationship will be eliminated (Manoochehri G. & Lindsy C., 2008). Further, from the bidders' prospect, the overall satisfaction of buyer-supplier's relationship will be decreased if there are too many bidders in RAB. the balance between competition needs to be maintained. The statistic data reveals that the

satisfaction increase as the number of bidder increase to 12 bidders per RAB and drops once the number exceed it (Jap, 2007). It is possible that bidders lose their interest and refuse to bid against the aggressive bidders in RAB.

However, Jap (2007) argues that the benefits of suppliers by using RAB are not neglect. Reverse auction bidding can reduce the complexity of bidding process since the RAB utilizes the internet, and the submission of bids are through online tools in a given time frame with an exact transaction. As long as the winner has been selected, the supplier can rapidly execute contracts so that they eliminate the time waste due a protected contract awarding process compare to traditional bidding. Further, a transparency bidding process makes the suppliers clearly understand the mechanism of winner selection procedure, which is fairer than an opaque sealed bid transaction.

In order to resolve the hazardous of buyer-supplier's relationship brought by reverse auction bidding, several solutions are proposed. One of the most prevalent research topics of RAB is that to adopt multi-attribute reverse auction bidding instead of considering price reduction as the only factor to evaluate the suppliers. Multi-attribute RAB enables buyers to evaluate the supplier's comprehensive capacity of providing the goods or services. In multi-attribute RAB, buyers qualify the suppliers based suppliers' previous experiences, the qualities of products and suppliers' financial statements. The mechanism of selecting a winner becomes comprehensive. Since other factors are introduced into RAB of selecting the winner, suppliers' concern about the buyer's opportunism can be reduced.

Human Intelligent Computer Program in Financial Trades

Experiments on human's reaction time have been studied for over a century. Kosinski (2012) developed a comprehensive literature review on human being's reaction time. Three major categories of reaction time experiments were conducted, which are simple reaction experiment, recognition reaction time experiment, and choice reaction experiment. The mean of human being's simple reaction time is 200 millisecond. The more complex the experiment was, the longer the participant's reaction time was tested. Some other factors have been studied and analyzed by the series experiment of reaction time. However, human being's average reaction time is much longer than a computer's.

In an RAB, the time of collecting information (receive the declined price on screen), analyze the information (comparing other bidder's prices) and react to the information (whether to reduce one's own price or not) consists a human bidder's reaction time. Hasbrouck (2013) addressed, "a faster speed than any other traders enables the prompt response to news or market activity" which can determine a trader's profit pattern.

Genetic programming is a human intelligent computer program which has been utilized in the foreign exchange and stock market. As an artificial tool, computer program can mimic the human traders' decision-making and behaviors in the equilibrium selections in a trade market (Manahov, 2013). Some people argue that the application of computer programs in trading market improved the trading frequency, which may have negative impacts on the market efficiency. The example is given that

NASDAQ has experienced many losses due to the trading programming being unable to handle the order submission and cancelations generated by high-frequency trades. However, both Hasbrouck and Manahov analyzed NASDAQ order-level data and concluded that high-frequency trading has a positive impact on market quality.

No matter how people argue about the influences of utilizing a computer program in trading market, the application of genetic programming is a release of manpower.

Previous Studies of RAB in Texas A&M University

A series of research of reverse auction bidding are being undertaken in Texas A&M University Construction Science department. The reverse auction bidding game was designed by Van Vleet in 2004. Students and industrial professions were invited to participate the experiment. Chouhan (2009) collected the personality type of participants according to Keirsey Temperament Sorter. Saigaonkar (2010) analyzed the impact the personality type and data; they further revealed that there are three personality types in the controlled game and suggested the Guardians have a better perform.

Chaudhari (2009) extended the RAB research of the owner's interference in reverse auction bidding. This research showed the negative impact that owner interference had on the relationship between the bidders. Further, Yuan Shu (2013) conducted the bid arrivals analysis to help further understand "early bidding" and "bid snipping" phenomenon. Discovered by Shmueli's eBay bid arrivals research (Shmueli et al., 2004), Shu tested whether the bid arrivals follows a Poisson process. Her work is based on the data collected from previous TAMU RAB experiments.

Personality Test

Originally proposed by Rogers (2010), the Keirsey Temperament Sorter Test was the tool to be utilized to find out the differences in personality between a Type ξ and Type ζ types (Yuan Shu, 2013). 71 questions were included in the Keirsey Temperament Sorter Test, which identifies 16 types of personalities. Chouhan (2009) used the Keirsey Temperament Sorter test to test the personality types of the bidder in an RAB. The personality types are categorized as SP – The Artisans, NT – The Rationals, NF- The idealists and SJ – The Guardians.

The Table 1 summarized the Keisey temperament sorter test. The Table 2 shows the individual components in the temperament scale. (Yuan Shu, 2013).

The personality type has an impact on the return in RAB (Gupta, 2010). Previous research shows generally that the Guardian has the best bidding performance in comparison to other personality types. (Kumar, 2014). However, the complexity of personality cannot be neglected. In 2013, Piper has conducted an RAB game, his research indicated an Idealist has rewarded the highest profit return who has beaten other three guardians. Further studies need to be completed on personality impact in RAB.

Table 1
Keirsey Temperaments

		Temperament	Role	Role Variant
Introspective (N)		Idealist (NF) *Diplomatic*	Mentor (NFJ) *Developing*	Teacher (ENFJ): *Educating*
				Counselor (INFJ): *Guiding*
			Advocate (NFP) *Mediating*	Champion (ENFP):
				Healer (INFP): *Conciliating*
		Rational (NT) *Strategic*	Coordinator (NTJ)	Field marshal (ENTJ):
				Mastermind (INTJ):
			Engineer (NTP) *Constructing*	Inventor (ENTP): *Devising*
				Architect (INTP): *Designing*
Observant (S)		Guardian (SJ) *Logistical*	Administrator (STJ)	Supervisor (ESTJ): *Enforcing*
				Inspector (ISTJ): *Certifying*
			Conservator (SFJ)	Provider (ESFJ): *Supplying*
				Protector (ISFJ): *Securing*
		Artisan (SP) *Tactical*	Operator (STP) *Expediting*	Promoter (ESTP):
				Crafter (ISTP): *Instrumenting*
			Entertainer (SFP)	Performer (ESFP):
				Composer (ISFP):

Table 2

Personality Type Summary

#	Name	Meaning
E	Extraversion	Feel motivated by interaction with people. Tend to enjoy a wide circle of acquaintances, and *gain* energy in social situations
N	Intuition	More abstract than concrete. Focus attention on the big picture rather than the details, and on future possibilities rather than immediate realities
F	Feeling	Value personal considerations above objective criteria. In making decisions, often give more weight to social implications than to logic
J	Judgment	Plan activities and make decisions early. Derive a sense of control through predictability
I	Introversion	Quiet and reserved. Generally prefer interacting with a few close friends rather than a wide circle of acquaintances, and *expend* energy in social situations
P	Perception	Withhold judgment and delay important decisions, preferring to "keep their options open" should circumstances change
T	Thinking	Value objective criteria above personal preference. When making decisions, generally give more weight to logic than to social considerations
S	Sensing	More concrete than abstract. Focus attention on the details rather than the big picture, and on immediate realities rather than future

The Review of RAB system in TAMU

Van Vleet (2004) has developed a website which uses ASP program to simulate the RAB process. This website utilized Microsoft SQL Server to collect the bids and record the bidding time.

The RAB game rules were set up by Van Vleet, the specific rules are:

i. The duration of the game were nine consecutive weeks (Kumar, 2014).

ii. The costs for every job were estimated as $10,000. This price does not include the travel expenses and delivery costs. The values of travel and delivery costs are variable which are given based on the jobsite locations.

iii. Each bidder has $40,000 at the beginning of the game so that they can bid on three jobs. But if the bidder decided to bid on more than three jobs, they have to take a loan from the bank. The charge for each loan is $500.

iv. It is assumed the job can be completed by five days. However, this schedule does not include the rain delay. In order to create a realistic game environment, the rain delays are considered as well.

v. Since the estimated cost for all jobs is $10,000, and the duration is five days, so that each day, the job will cost $2000. Travel costs and delivery expenditures will be added on a daily basis in accordance with the job site location.

vi. It is assumed the project owner are located at Sugar Land, Texas. The travel and delivery costs are calculated based on the distances between each job

site and the owner's site. In addition, it is assumed the subcontractors are located in the Sugar Land, Texas.

vii. The work will be paid at the completion of fifth construction day.

Rain Delay

A realistic game environment can generate a better result of the experiment which helps people to understand the human's reaction in RAB game. The game rule was set up by Van Vleet. It assumed the RAB game occurs during May to July in Houston, where has high rainfall period from May to July. Based on National Oceanic and Atmospheric Administration (NOAA, 2010) data, which describes the probability of rain in Houston from May to July. The Figure 2 indicates the rain distribution.

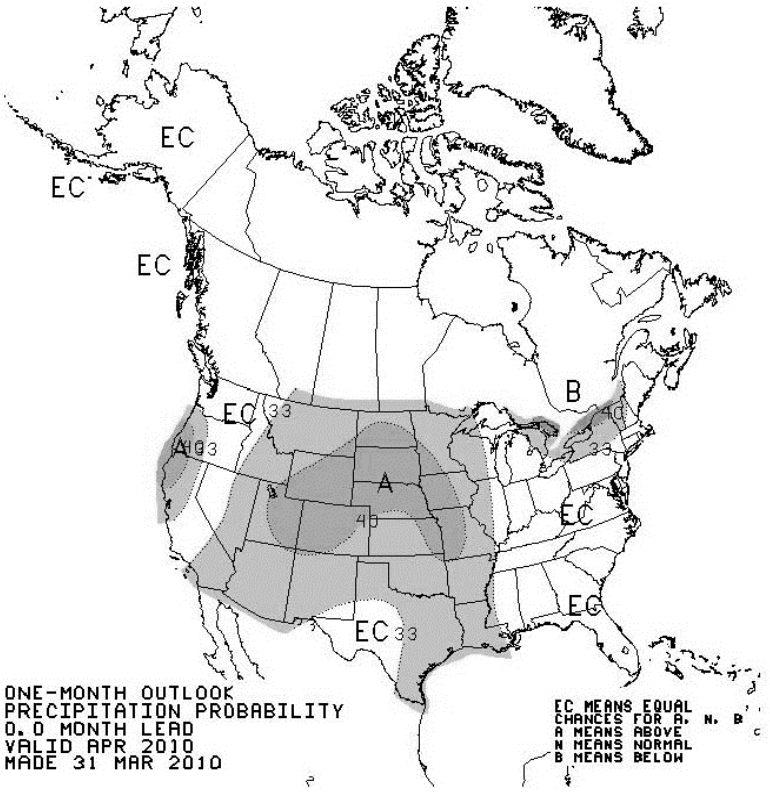


Figure 2 The Rain Probability

If jobs experience rain delay, they will be considered as incomplete job. Rain delays will influence the bidding process by increasing the travel costs and delivery costs.

Table 3 below shows rain delay matrix. "1" represent a rainfall day, "0" represent no rainfall. It is assumed there is no correlation between the site location and the rainfall in a vicinity.

Table 3
Rain Delays for Week One

Day	Site					
	One	Two	Three	Four	Five	Six
Monday	1	0	0	0	1	0
Tuesday	0	1	1	0	0	0
Wednesday	0	0	0	0	0	0
Thursday	0	0	1	0	0	1
Friday	1	0	0	0	1	1
Saturday	0	0	0	0	0	0

Jobsite Locations

Van Vleet (2004) has selected six jobsite locations, namely, Brookside Village, Piney Point Village, Highlands, Jersey Village, Bunker Hill Village and Richmond. Table 4 indicates all the delivery and travel costs from the jobsite to owner's office which located at Sugar Land, Texas.

Table 4
Location of the Construction Sites in Houston

Site #	Location of Development	Distance from Sugarland (Km)	Travel Cost ($)	Delivery Cost ($)	Total Cost ($)
Site 1	Brookside Village	67.6	858	624	1482
Site 2	Piney Point Village	38.6	495	360	855
Site 3	Highlands	112.6	1452	1056	2508
Site 4	Jersey Village	64.37	825	600	1425
Site 5	Bunker Hill Village	43.45	561	408	969
Site 6	Richmond	22.53	297	216	513

Figure 3 indicates the jobsite locations.

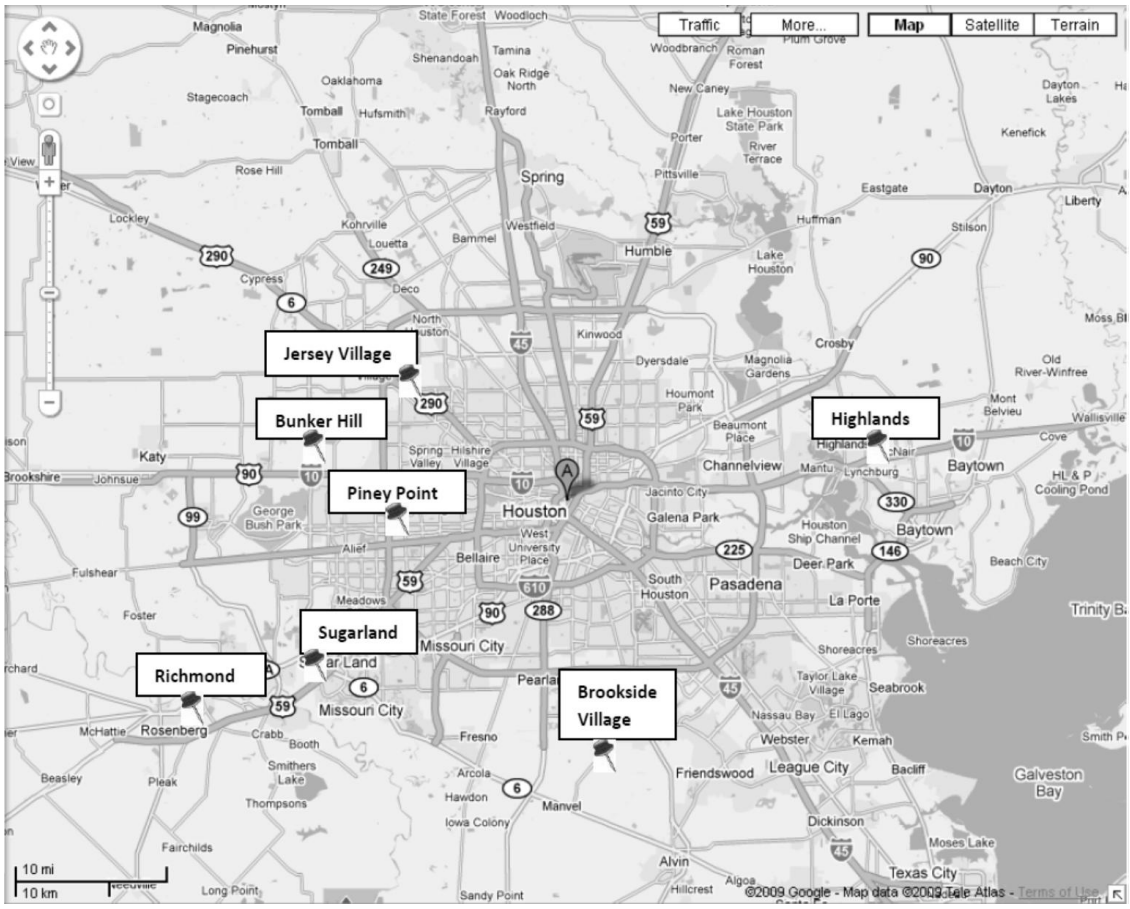


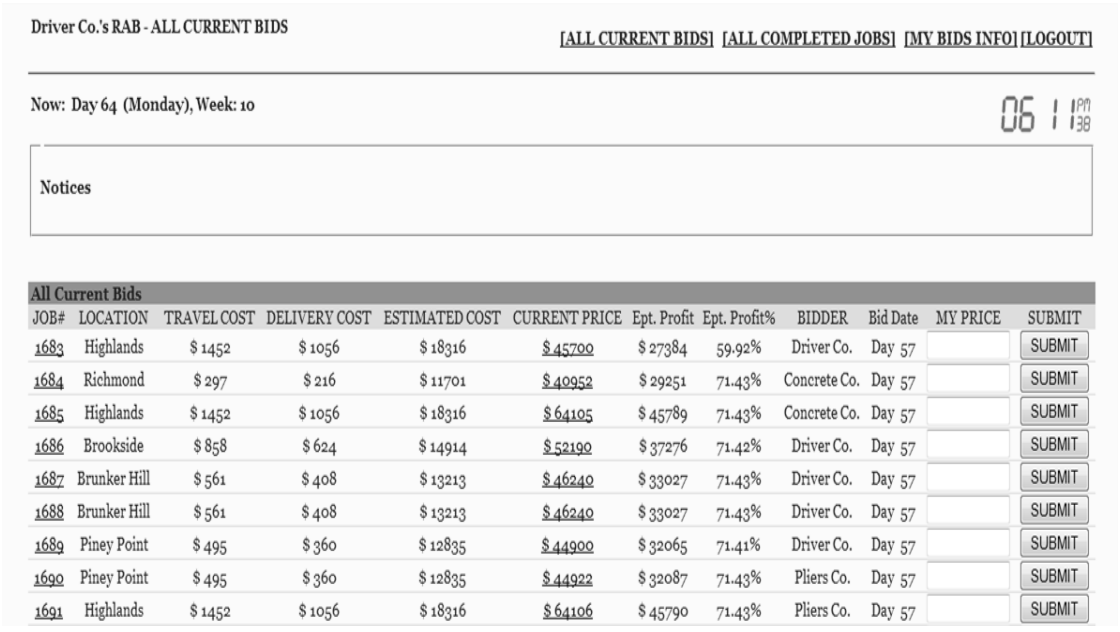
Figure 3 Job Site Locations

Data Collection

Wellington (2006) changed the game to Sequential Query Language (SQL) in order to enable efficient multiple bidding. Participants of RAB game are assigned a username and password. Once the bidders login to the website, they can know all information about the contract. For example, other bidder's username, all current bids and their costs of each job is show on the main screen.

Once a bidder logs on to the server, the bidders can see the current bids screen as shown in Figure 4. The current bids screen includes jobsite locations, the delivery and travel costs, approximate profit and profit percentage. In addition, there is an empty column named My price, by input the price number into “my price” column, and then click on “submit” bottom, the bidder can submit their bids.

There are nine bidding sessions, each of the bidding session was 15 minutes. Between each bidding session, there were 5 minutes breaks. Bidders were only able to submit their bids during the bidding session.



Driver Co.'s RAB - ALL CURRENT BIDS

[ALL CURRENT BIDS] [ALL COMPLETED JOBS] [MY BIDS INFO] [LOGOUT]

Now: Day 64 (Monday), Week: 10

06 11 PM 38

Notices

All Current Bids

JOB#	LOCATION	TRAVEL COST	DELIVERY COST	ESTIMATED COST	CURRENT PRICE	Ept. Profit	Ept. Profit%	BIDDER	Bid Date	MY PRICE	SUBMIT
1683	Highlands	$ 1452	$ 1056	$ 18316	$ 45700	$ 27384	59.92%	Driver Co.	Day 57		SUBMIT
1684	Richmond	$ 297	$ 216	$ 11701	$ 40952	$ 29251	71.43%	Concrete Co.	Day 57		SUBMIT
1685	Highlands	$ 1452	$ 1056	$ 18316	$ 64105	$ 45789	71.43%	Concrete Co.	Day 57		SUBMIT
1686	Brookside	$ 858	$ 624	$ 14914	$ 52190	$ 37276	71.42%	Driver Co.	Day 57		SUBMIT
1687	Brunker Hill	$ 561	$ 408	$ 13213	$ 46240	$ 33027	71.43%	Driver Co.	Day 57		SUBMIT
1688	Brunker Hill	$ 561	$ 408	$ 13213	$ 46240	$ 33027	71.43%	Driver Co.	Day 57		SUBMIT
1689	Piney Point	$ 495	$ 360	$ 12835	$ 44900	$ 32065	71.41%	Driver Co.	Day 57		SUBMIT
1690	Piney Point	$ 495	$ 360	$ 12835	$ 44922	$ 32087	71.43%	Pliers Co.	Day 57		SUBMIT
1691	Highlands	$ 1452	$ 1056	$ 18316	$ 64106	$ 45790	71.43%	Pliers Co.	Day 57		SUBMIT

Figure 4 Current Bid Screen From RAB Website

Each bidder can only bid on three jobs within a given week. If the bidders want to bid on more jobs, they can take a loan from the bank. The charge for each loan was $500, which will be automatically deducted from their account.

Figure **5** below indicates the bank loan form.

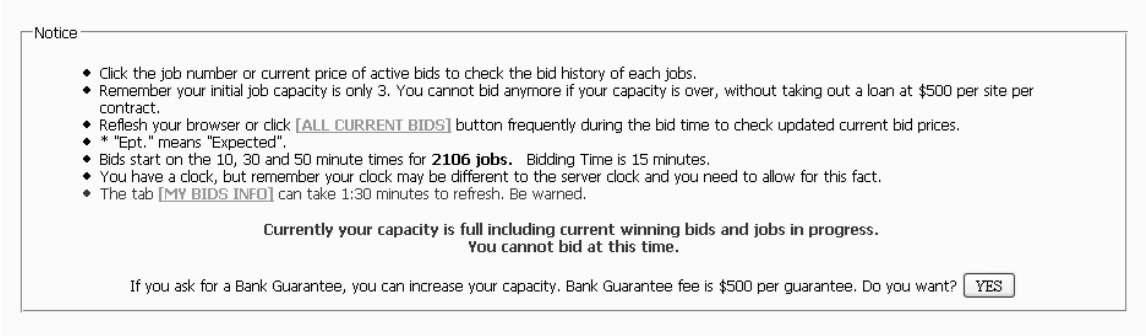


Figure 5 Bank Loan Form

Since in an RAB game, the bidders were only allowed to provide a price, which is lower than the current lowest bid. If the bidder submits a bid, which is higher than the current lowest bid, the following notification will appear on their screen (See Figure 6).

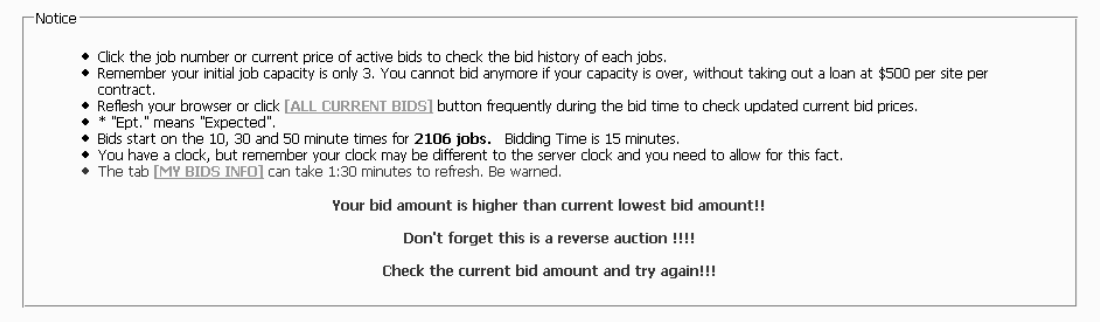


Figure 6 Higher Than Current Lowest Bid Statement

The bid will be awarded to the lowest bidder at the end of each 15-minute bid session. The bidders were able to go to the "my jobs in progress" website (see Figure 7) to view what jobs did they win.

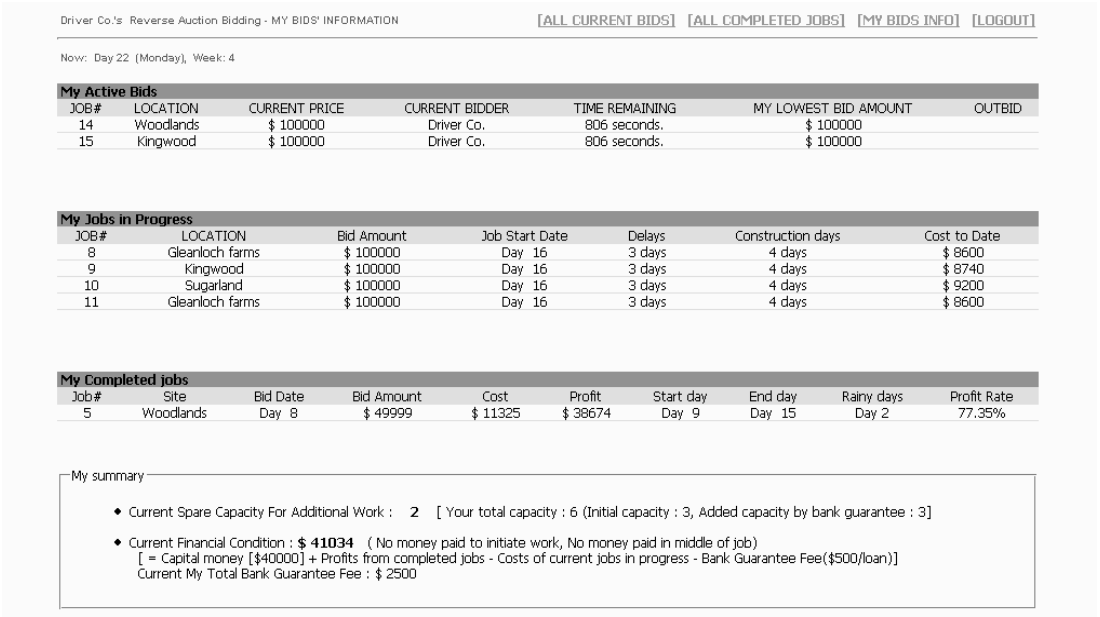


Figure 7 My Bid Information Web Page

CHAPTER III

METHODOLOGY

Introduction

This chapter outlines the methodology utilized to analysis the bid data. By observing the time data collected from previous Reverse Auction Bidding games conducted in TAMU, the research determined that human bidders bid time interval is approximately 2 second. This chapter describes the data analysis process, including the data sources and data reorganization.

Data Source

Since Van Vleet developed the RAB game from 2004, 25 case studies were conducted in TAMU. This research is the 26th case study of Reverse Auction Bidding. The research data were collected from previous RAB research experiments.

The participants of RAB game were construction science students and construction professions. All of the participants have the same level of knowledge about RAB game. In addition, the participants played the role of contractors, who compete against each other by reducing their bid prices. Each game has the maximum of 9 sections, and each section has 15 minutes. In addition, in between of two sections, there was 5 minute breaks. During the 15 minutes' bidding time, the bidders can submit their bids at any time, as long as their bid's price is lower than the current lowest price. At the end of each game, the jobs were awarded to the lowest bidders.

W. Kim (2004) created the online RAB system, Wellington (2006) recreated the system with SQL Server. All the RAB game data are collected and then transferred to

Microsoft Access, which include the bid ID, Job ID, Control ID, bid prices and bid time. 7 sets of data to analyze the bid time intervals.

Table 5 gives an example of bid information contained in a typical Microsoft Access database.

Table 5
Original Access Dataset Sample 1

bidID	jobID	ctrID	bidAmount	bidDate	bidTime
5	1	4	$12,999.00	1	7:01:02 PM
19	1	4	$12,400.00	1	7:02:21 PM
88	1	4	$12,150.00	1	7:11:48 PM
105	1	7	$12,149.00	1	7:13:27 PM
2	1	8	$13,000.00	1	7:00:22 PM
11	1	8	$12,500.00	1	7:01:39 PM
22	1	8	$12,200.00	1	7:02:52 PM
1	1	9	$15,000.00	1	7:00:20 PM
115	1	9	$12,000.00	1	7:14:16 PM
62	2	4	$12,999.00	1	7:09:30 PM
89	2	4	$12,450.00	1	7:11:52 PM
95	2	4	$12,200.00	1	7:12:22 PM
104	2	4	$12,100.00	1	7:13:20 PM
8	2	7	$13,500.00	1	7:01:29 PM

Table 6 gives an example of job information collected in the database.

Table 6
Original Access Dataset Sample 2

jobID	siteID	jobPrice	ctrID	jobBidStartTime	jobBidEndTime
1	6	12000	9	5/4/04 7:00 PM	5/4/04 7:15 PM
2	5	12100	4	5/4/04 7:00 PM	5/4/04 7:15 PM
3	5	11999	7	5/4/04 7:00 PM	5/4/04 7:15 PM
4	5	12000	9	5/4/04 7:00 PM	5/4/04 7:15 PM
5	6	11750	8	5/4/04 7:00 PM	5/4/04 7:15 PM
6	4	11999	7	5/4/04 7:00 PM	5/4/04 7:15 PM
7	3	12300	9	5/4/04 7:00 PM	5/4/04 7:15 PM
8	4	11999	4	5/4/04 7:00 PM	5/4/04 7:15 PM
9	3	12499	7	5/4/04 7:00 PM	5/4/04 7:15 PM
10	1	12300	8	5/4/04 7:00 PM	5/4/04 7:15 PM
11	1	12000	9	5/4/04 7:00 PM	5/4/04 7:15 PM
12	1	12300	8	5/4/04 7:00 PM	5/4/04 7:15 PM
13	2	10900	6	5/4/04 7:00 PM	5/4/04 7:15 PM
14	4	12000	4	5/4/04 7:20 PM	5/4/04 7:35 PM
15	4	12450	4	5/4/04 7:20 PM	5/4/04 7:35 PM

Data Reorganization

The research utilized 7 sets of data. For each set of data, the research categorized the bids by their bidding sections, each section has 15 minutes which the bidders can submit their bids.

The key characteristics of the data set are:

- A count of number of bidders yields 59.
- A count of the number of experiments yields seven.
- A count of the number of bidding sections yields 54.

- A count of the number of projects yields 480.
- A count of the number of bids yields 4614 valid bids

Table 7 indicates a summary of bid and record data for the 7 case studies.

Table 7
Bid and Record Data Summary

Experiment Date	Case Study ID	Number of Contractors	Number of Section	Number of Projects	Number of Bids
5/4/2004	1	5	9	86	744
11/5/2007	4	4	4	43	334
4/6/2010	5	5	8	54	805
4/3/2010	6	5	4	58	284
6/11/2010	9	4	9	59	904
6/08/2010	11	4	9	107	839
09/21/2010	15	5	9	73	704
Total		59	54	480	4614

Bidding Segment Definition

Each bidding section includes 15 minutes bidding time, this research has divided each bidding sections into 2 categories or segments to provide for a time difference analysis. Bidding section segment 1 includes all the bid information obtained from 1

seconds to 7 minutes and 30 seconds. Bidding section segment 2 include all the bid information obtained from 7 minutes 31 seconds to 15 seconds.

In each 15 minutes' bidding section, the data has been divided into two segments by the bids arrival time, namely, segment 1 and segment 2. Segment 1 contains all the bids from the first second to 7 minutes 30 seconds, which is half time of a bidding section. Segment 2 contains all the bids received from 7 minutes 30 seconds to 15 minutes.

The reorganized data sets are named as the case study 1-section 1-segment 1, case study 1-section 1-segment 2 and so on.

The Figure 8 indicates how the data were divided.

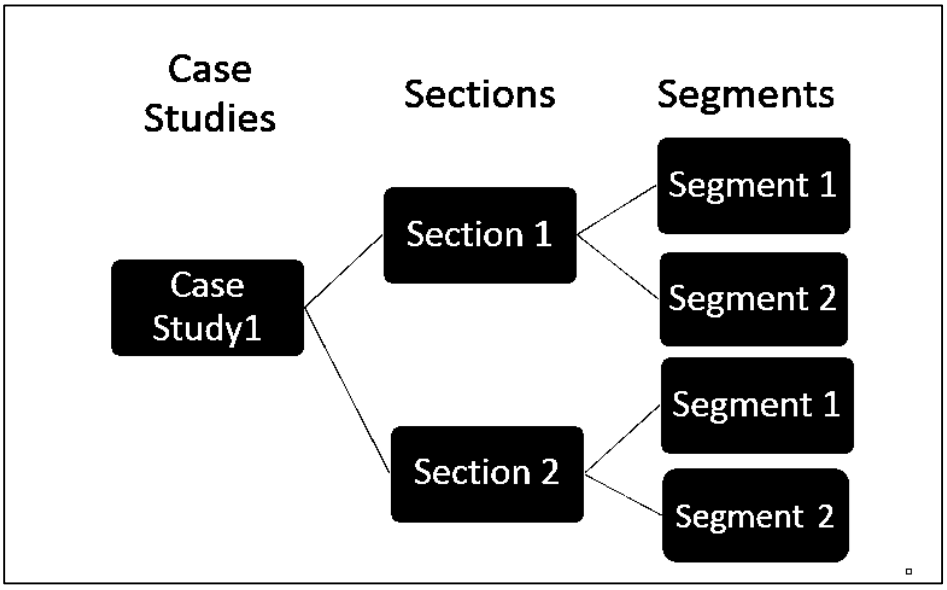


Figure 8 Data Reorganization Schematic

The key characteristics of the data set are:

i. A count of number of bidding sections is 54.

ii. A count of number of bidding segment is 108.

The last step of data reorganization is to recombine each case study's segment 1 data into one dataset, and to recombine the segment 2 data into another dataset. To name them as the case study 1-accumulated segment 1 data, case study 2-accumulated segment 2.

The Figure 9 indicates the accumulated data segment of each case studies.

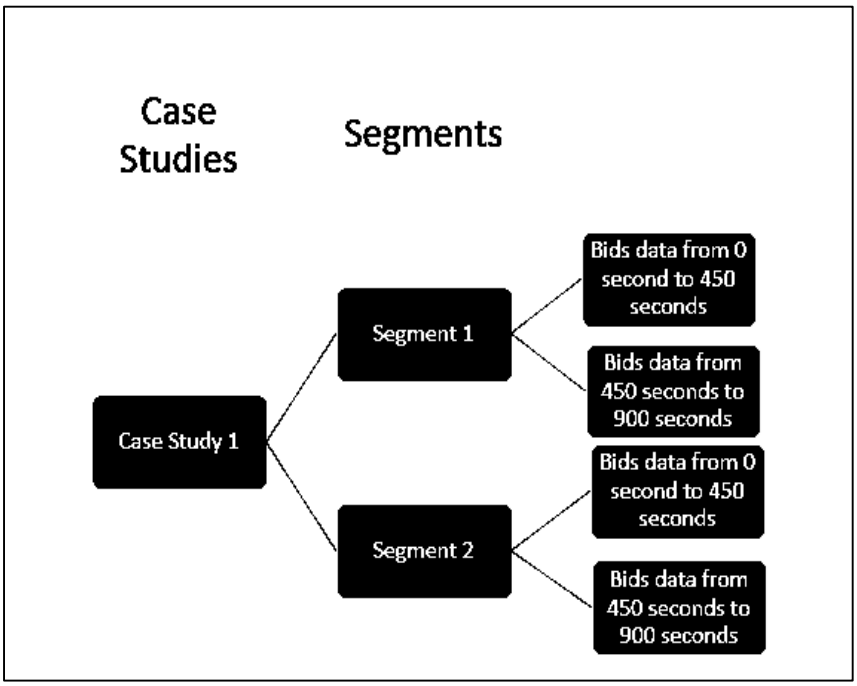


Figure 9 Accumulated Data Segment

CHAPTER IV

RESULTS

Introduction

This chapter describes the analysis of the data and the results of the research. This chapter summaries single segment data analysis, accumulated segment data analysis, the special case, bid time-intervals comparison and summary.

Single Segment Data Analysis

The point of the study is to look at the distribution of the time intervals between the bids. The single segment data analysis uses a histogram figure and linear regression analysis. A typical bidding interval time breakdown is shown on Figure 10, which is the histogram result of case study 9-section 1-segment 1. The most bids time intervals are within 5 seconds.

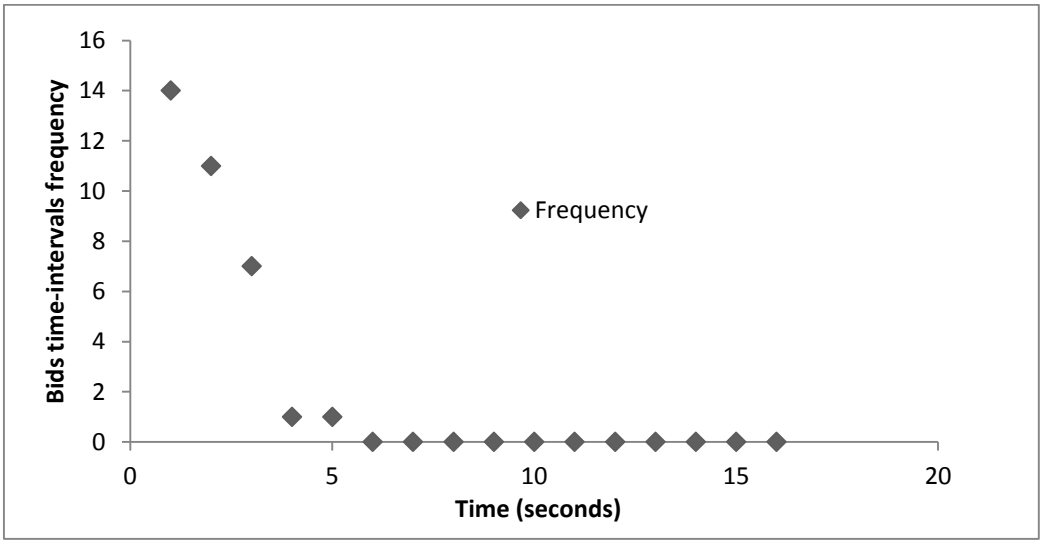


Figure 10 Bids time-intervals When Time Interval is 10 Seconds of case study 9 section 1 segment 1

However, there time-intervals are appeared after 5 seconds, which means, most of the people bidding within 5 seconds after a new lowest bid has appeared on their screen. The research has analyzed the bid time-intervals of all the case studies.

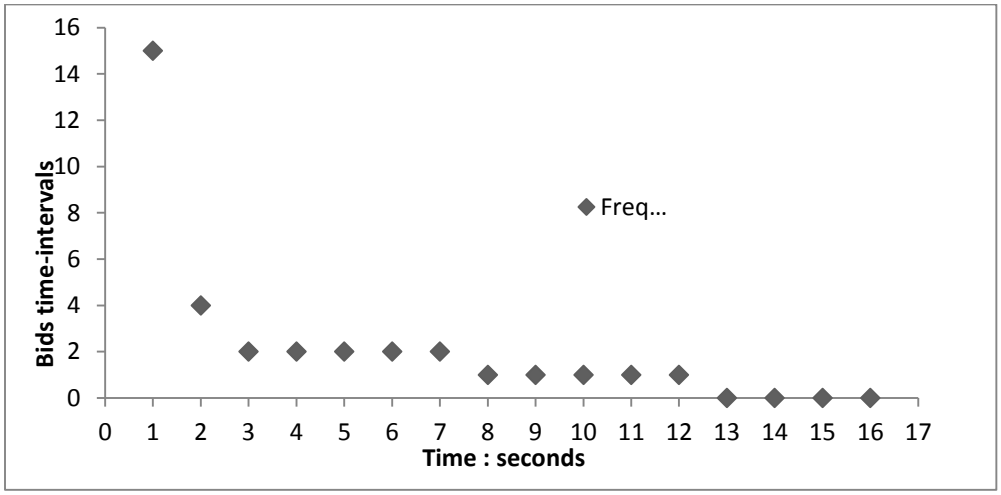


Figure 11 Bids time-intervals When Time Interval is 1 Seconds of case study 9 section 1 segment 1

Figure 11 shows there are more bids time-intervals located within 5 seconds.

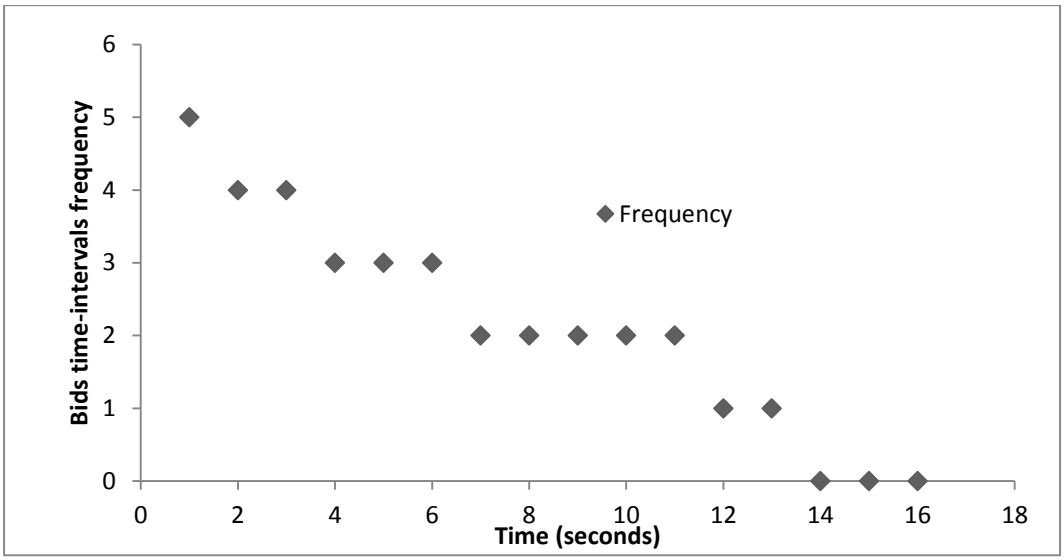


Figure 12 Bids time-intervals When Time Interval is 2 Seconds of case study 9 section 1 segment 1

Figure 12 shows when the time-axle is 2 seconds, the most bids time-intervals are located within 5 seconds, fewer bids time-intervals are observed after 5 seconds.

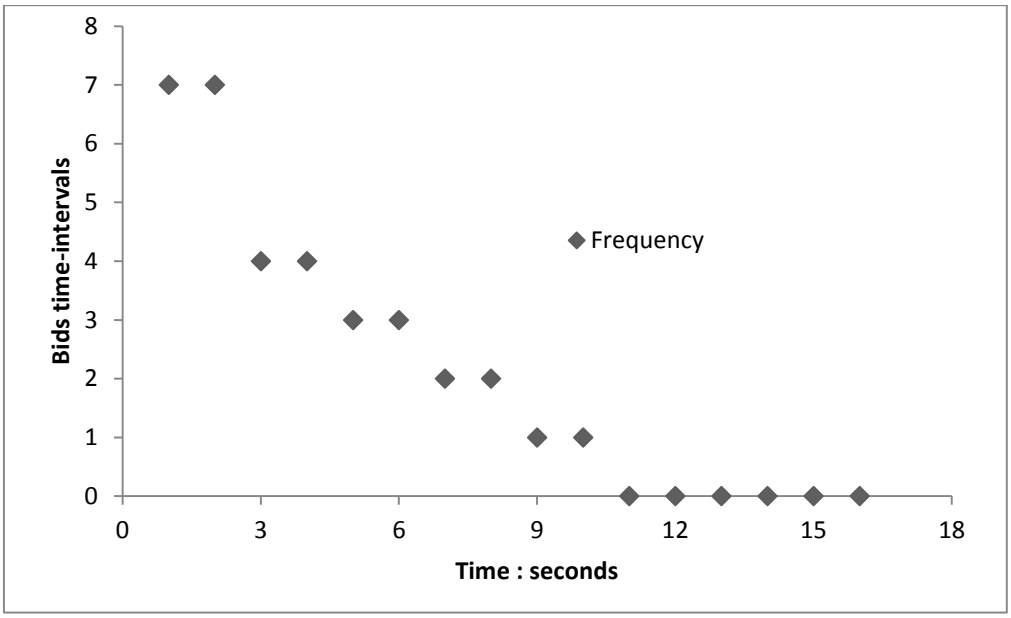


Figure 13 Bids time-intervals When Time Interval is 3 Seconds of case study 9 section 1 segment 1

Figure 13 shows when the time-axle is 3 seconds, then most bids time intervals are located within 10 seconds.

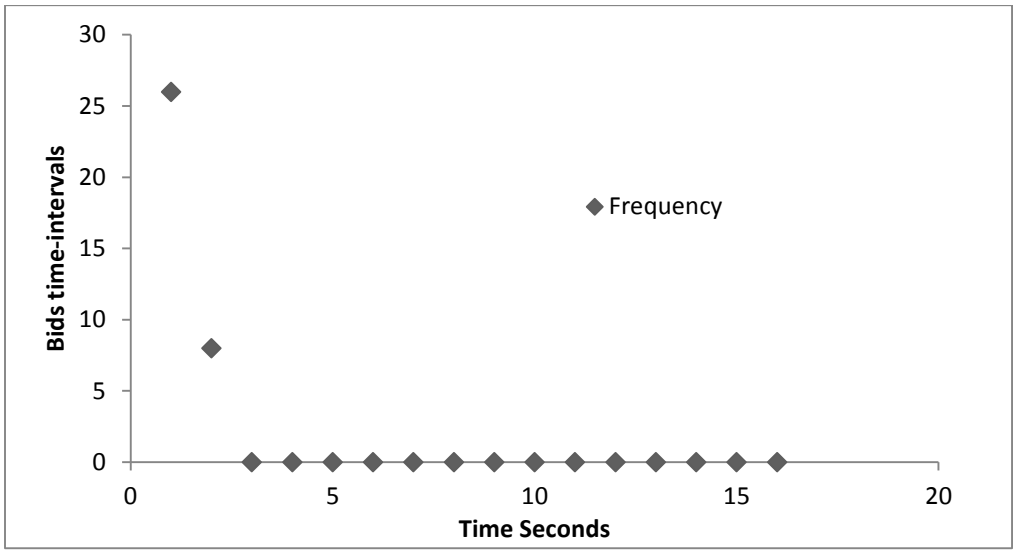


Figure 14 Bids time-intervals When Time Interval is 10 Seconds of case study 9 section 1 segment 2

Figure 14 is the histogram result of case study 9-section 1-segment 2. Most bids time intervals are within 10 seconds.

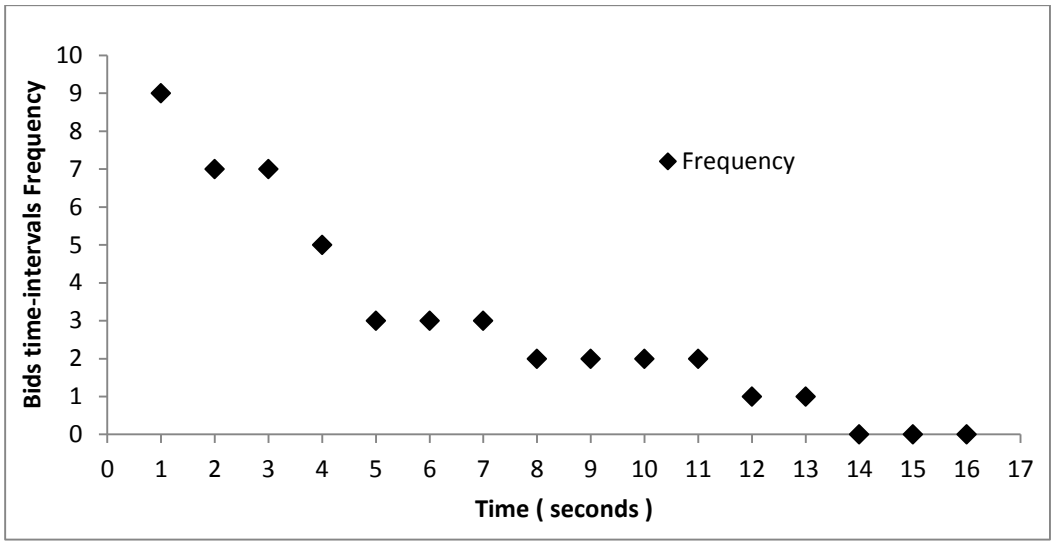


Figure 15 Bids time-intervals When Time Interval is 1 Seconds of case study 9 section 1 segment 2

Figure 15 is the histogram result of case study 9-section 1-segment 2 where the time-axle is 2 seconds. The most bids time intervals are within 1 seconds.

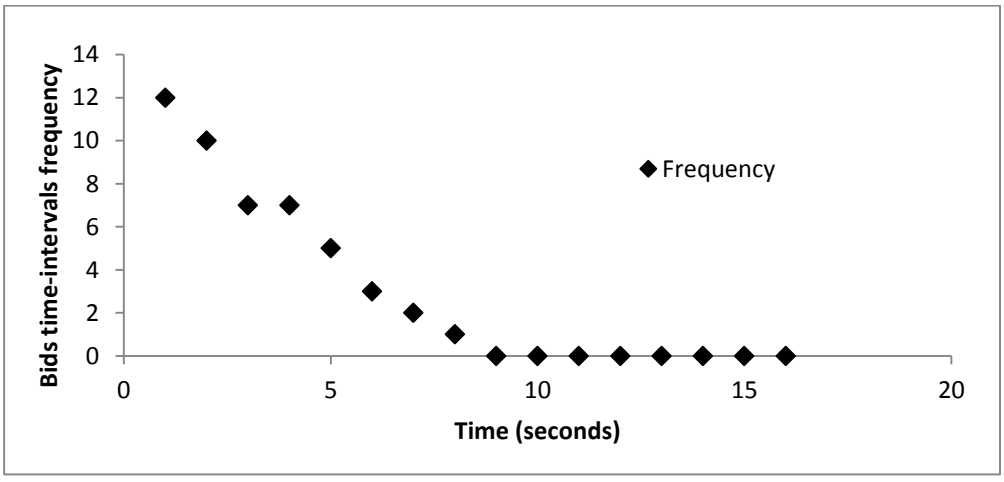


Figure 16 Bids time-intervals When Time Interval is 2 Seconds of case study 9 section 1 segment 2

Figure 16 is the histogram result of case study 9-section 1-segment 2 where the time-axle is 2 seconds. Most bids time intervals are within 8 seconds.

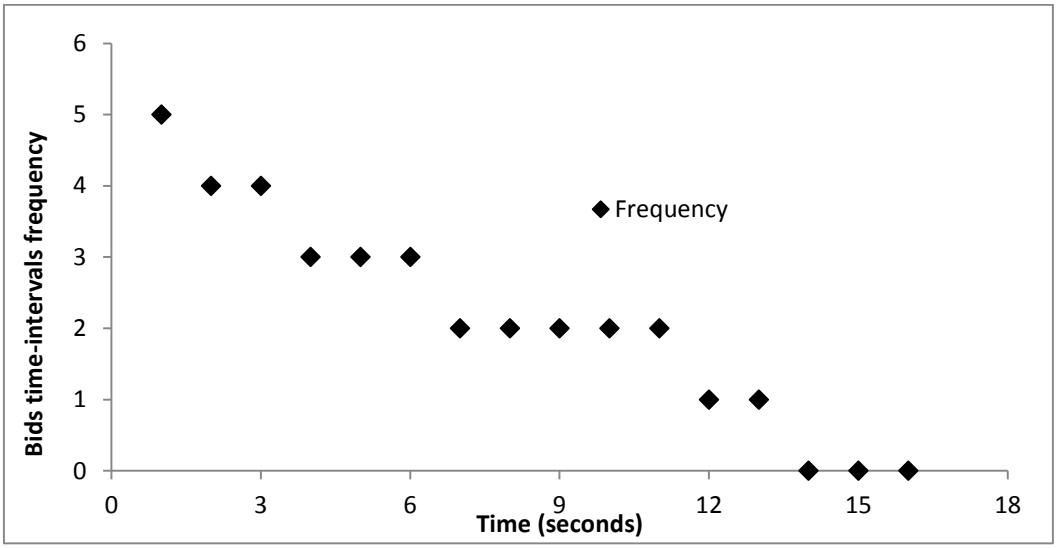


Figure 17 Bids time-intervals When Time Interval is 3 Seconds of case study 9 section 1 segment 2

Figure 16 is the histogram result of case study 9-section 1-segment 2 where the time-axle is 3 seconds. Most bids time intervals are within 12 seconds.

Further, the research compared the bid time-intervals in segment 1 and segment 2 of case study 9-section 1 by adopting a linear regression analysis. Figure 18 shows the comparison of the results.

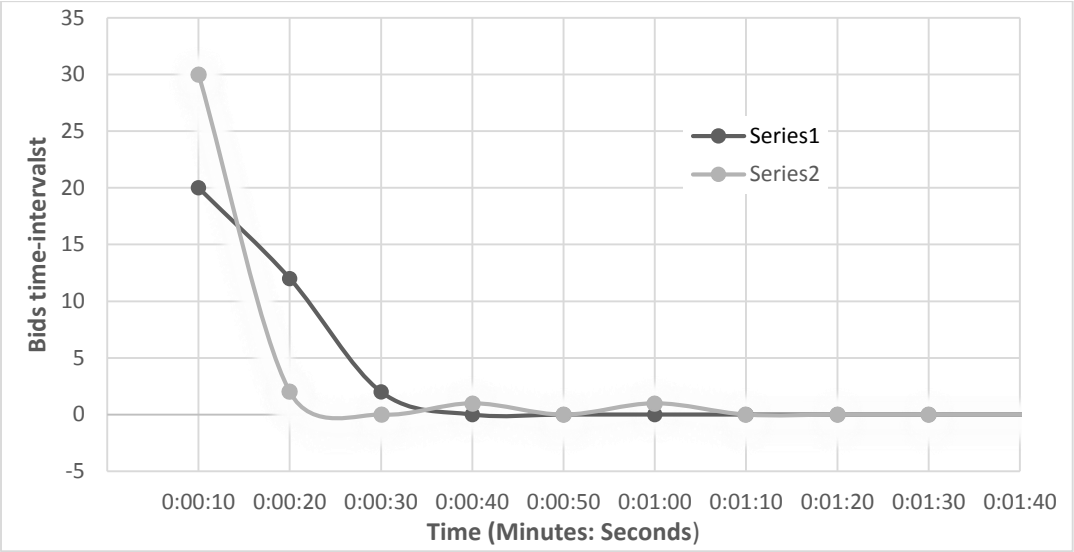


Figure 18 10 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 1

Figure 18 shows a high volume of bid time-intervals are located within ten seconds. However, after 10 seconds, segment 2 experiences a sharp drop of time-intervals. Segment 1 indicates most of the bid time-intervals are located in 10 seconds, there is a fewer bids time-intervals are located at 20 seconds. However, with the bidding process ongoing, there is fewer bid time-intervals appeared after 1 minutes and 10 seconds.

The bid time-intervals do not only represent the time difference, but also reflect the bids quantities. As we know, one bids time interval can represent 2 bids because we used one bid arrival time to subtract another bid arrival time. Therefore, in the graph, where a crest can represent a high volume of bids have received at that moment. By reviewing the data, it is believed there are more bids have been received within the

segment 2. Bidders submit more bids when the time goes towards the end of each section.

Since Figure 18 shows a smooth linear regression of the bids time-intervals of both segment 1 and segment 2. So that it is believed that 10 seconds is a relatively long time for the human bidders to react in a RAB game. The research further repeated the two steps as described above for the same set of data. However, the x-axes was reset as 1 seconds interval. The comparison of bids time-intervals in segment 1 and segment 2. When the time interval is 1 seconds is shown as Figure 19.

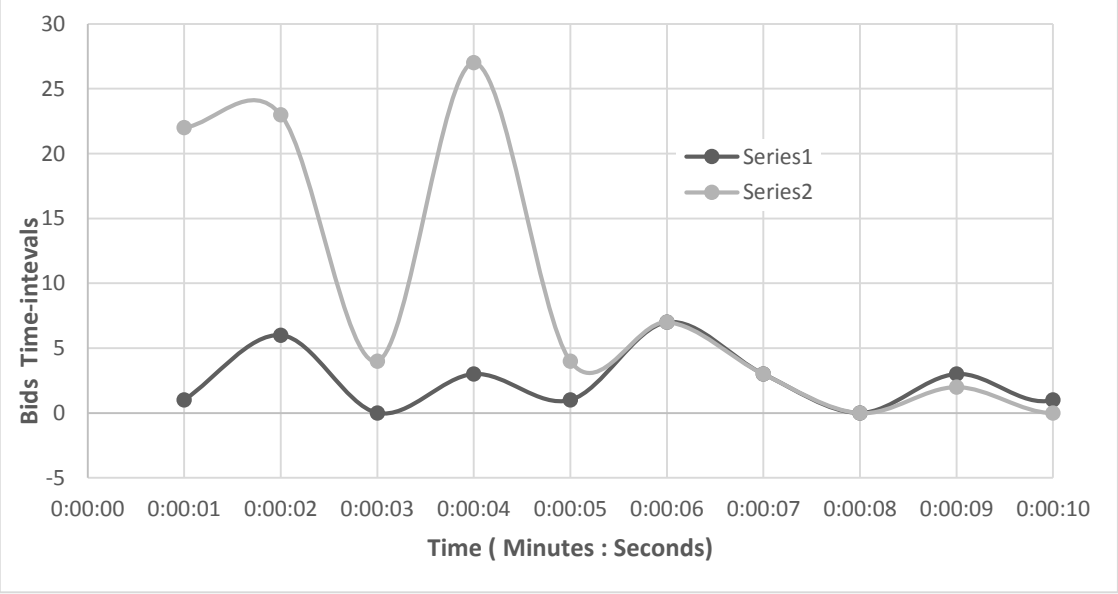


Figure 19 1 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 1

Figure 20 shows the fluctuation of bids time-intervals for both segment 1 and segment 2 are obvious. In between the two adjacent crests, where a high volume number of bids have received, there is a two seconds interval corresponding to each of the crests. It is likely the human bidder's reaction time is a minimum effective two second in an RAB game.

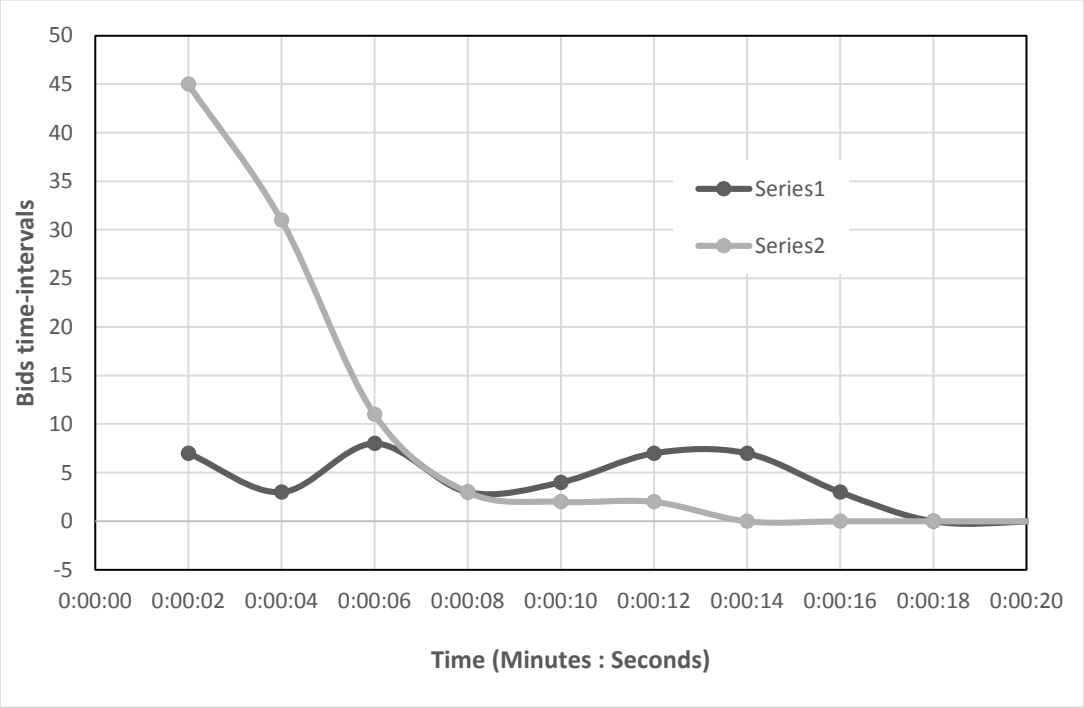


Figure 20 2 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 1

Figure 20 shows when the bids time-intervals are 2 seconds, the distribution of bids time-intervals smooth out.

Figure 21 shows, when the bids time-intervals are 3 seconds, the linear regression distribution is more close to curved lines.

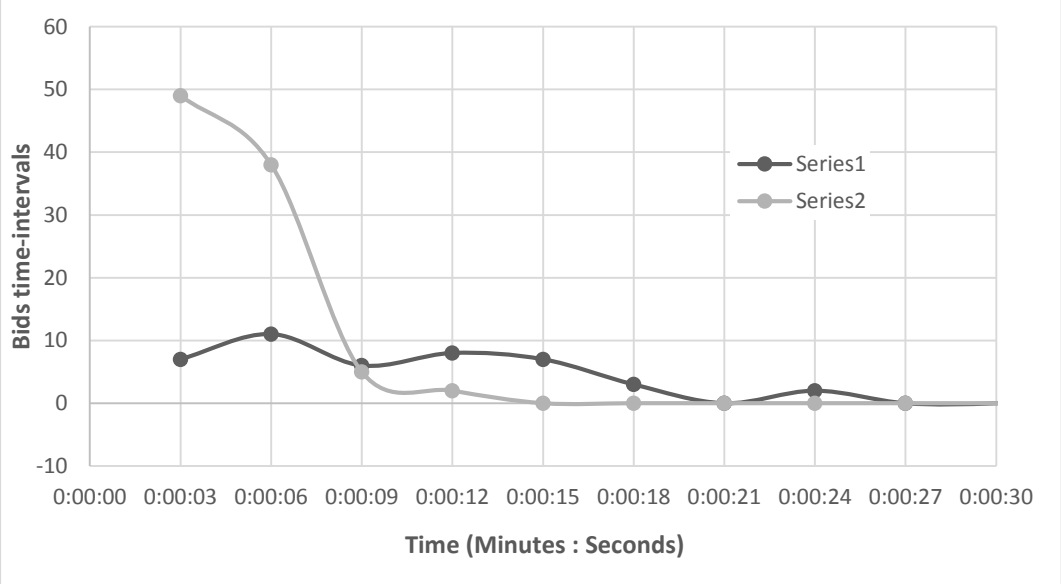


Figure 21 3 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 1

The research compared all the selected dataset separately by conduct the same test for 54 bidding sections. Ninety percent of the data shows the same figure shape as the result above. Additional examples of single segment analysis are given in the Appendix A.

Accumulated Segment Data Analysis

The research has further tested the accumulated datasets by using the same statistic technics as introduced above, to ensure the result is a universal character for all

the data. All the figures show very similar results as single segment data analysis. The figures below, Figure 22, Figure 23, Figure 24 and Figure 25, show the test results.

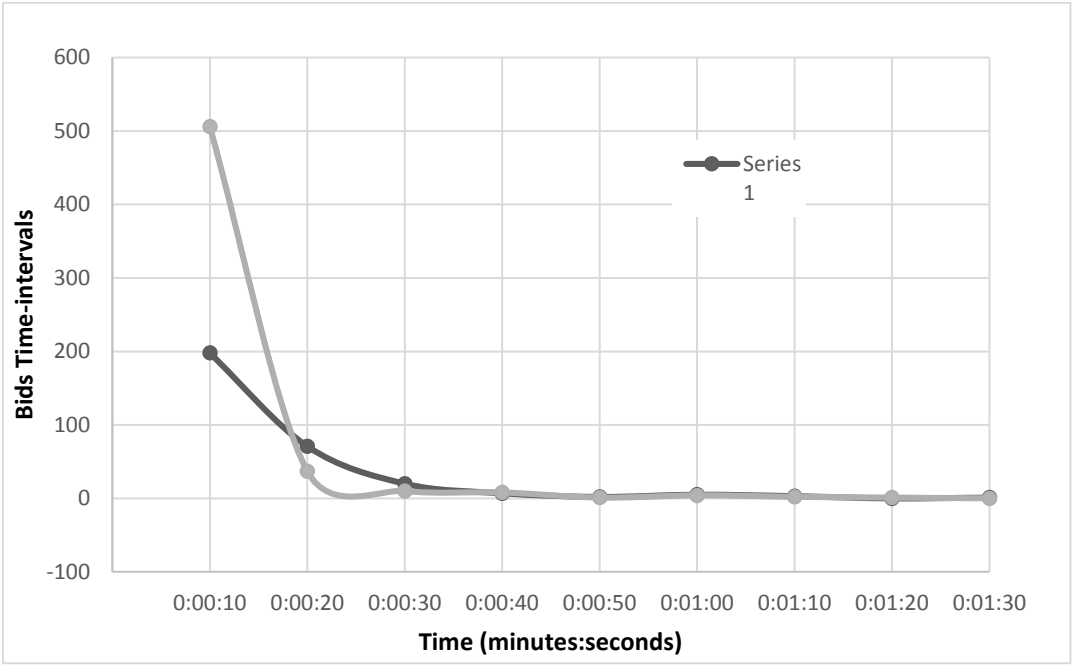


Figure 22 10 seconds bids Time-intervals comparison of accumulated segment 1 and segment 2 of case study 9

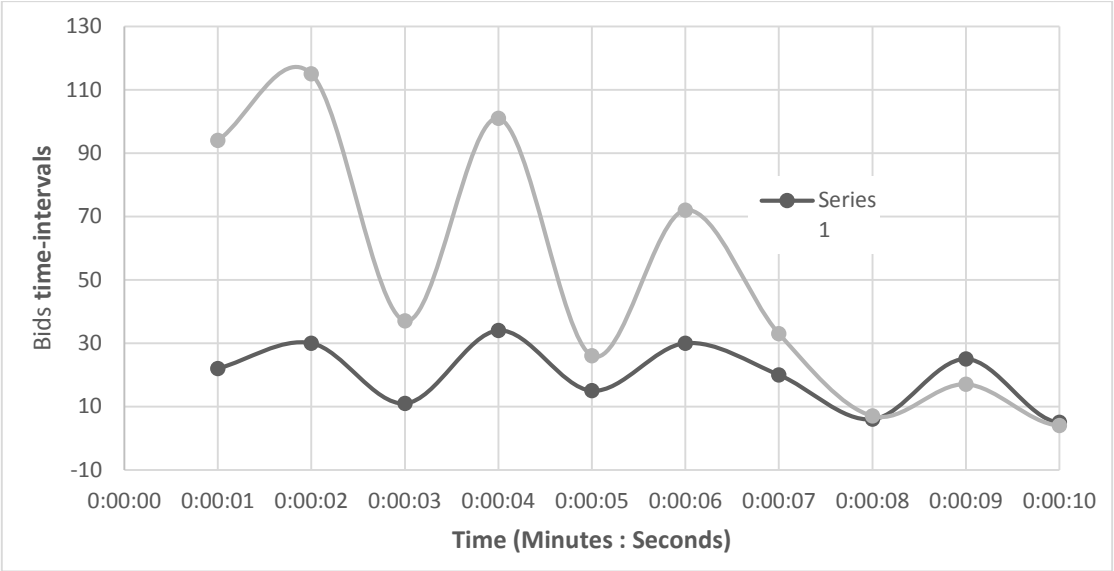


Figure 23 1 seconds bids time-intervals Comparison of accumulated Segment 1 and Segment 2 of case study 9

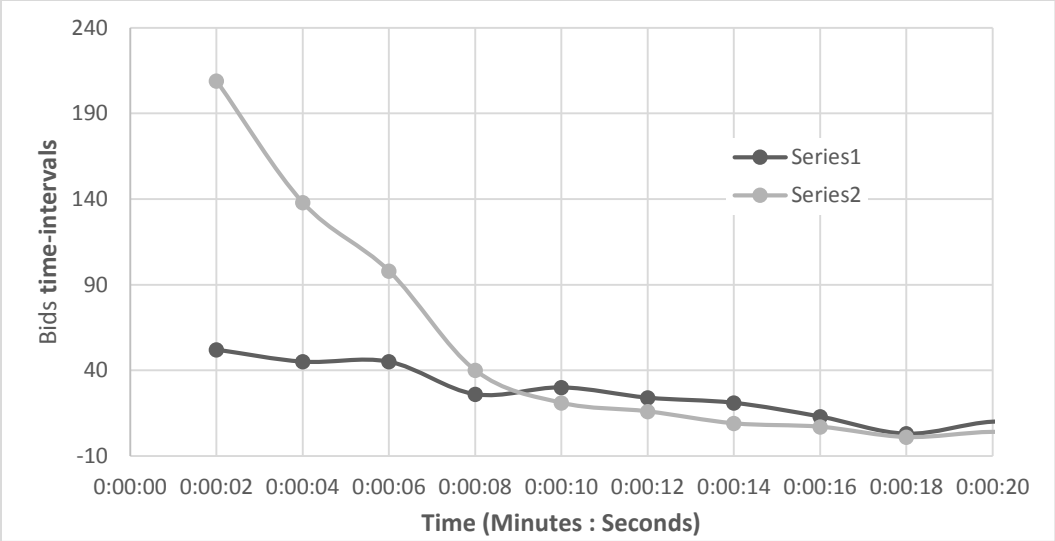


Figure 24 2 seconds bids time-intervals Comparison of accumulated Segment 1 and Segment 2 of case study 9

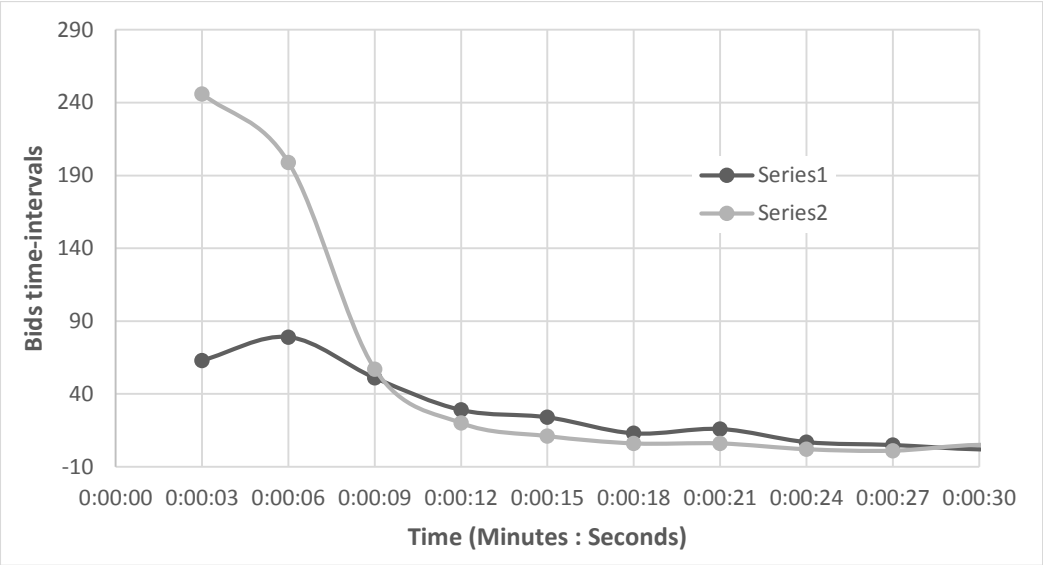


Figure 25 3 seconds bids time-intervals Comparison of accumulated Segment 1 and Segment 2 of case study 9

Both the single segment data and the accumulated data analysis indicate the same characteristics of the bid time-intervals. Smooth linear regression graphs result when the time intervals are 2 seconds, 3 seconds, and 10 seconds. When the x-axle are united with 1 seconds, the bids time-intervals appears an obvious fluctuation.

Special Case

Although 90% of the figures indicate very similar results when compare segment 1 bids time-intervals and segment 2 bids time-intervals in different time axes, the special cases exist in the data. The research cannot get a smooth bid time-intervals distribution when the time axes unite are 2 seconds and 3 seconds(see Figure 26 and Figure 27). In other words, when the time intervals are enlarged to 2 seconds and 3 seconds, an obvious crest and valley exists in the figures. The research observed these special sections. Moreover, all the sections received a significant smaller volume of bids. In these

sections, the bidders intended to bid less aggressive. Therefore, that a few bid were recorded in the server. The reason behind this phenomenon needs to be further analyzed.

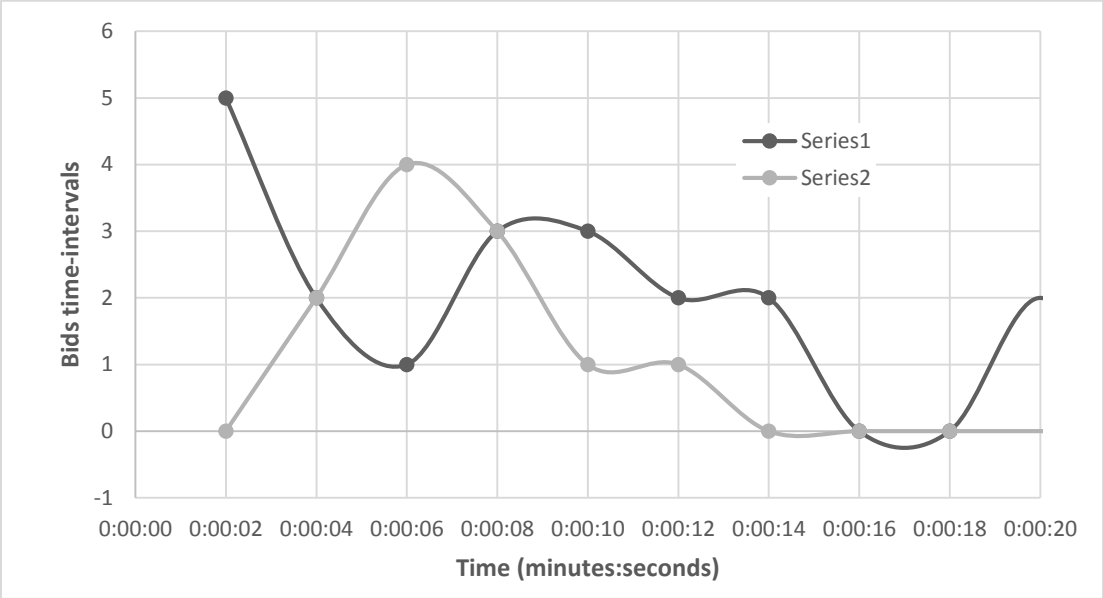


Figure 26 2 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 5

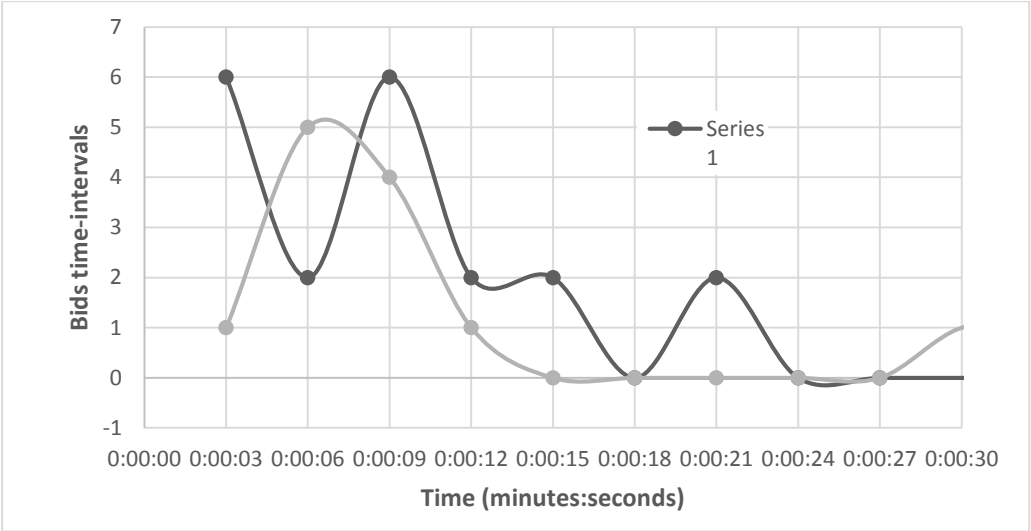


Figure 27 3 seconds bids time-intervals Comparison of Segment 1 and Segment 2 of case study 9 section 5

Bid Time-intervals Comparison

In segment 1, 90% of the bids time-intervals are located within 23 seconds. In segment 2, 90% of the bids time-intervals are located within 9 seconds.

This result can generate 2 bidding rules.

When the machine is bidding during segment 1, it should randomly select a time interval from 2 seconds to 23 seconds to bid against the human bidders.

When the machine is bidding during the segment 2, it should randomly select a time-interval from 2 seconds to 9 seconds.

Summary

The research has compared the figures resulted from single segment data analysis and the accumulated data analysis; it is believed the data has the same characteristics. All the data gives a smooth linear regression when the time intervals are 2 seconds, 3

seconds and 10 seconds. However, when the time intervals is 1 seconds, the data have an obvious fluctuate in both segment 1 and segment 2. Further, in between the data crest, there is 2 second-time intervals.

In addition, two rules can be applied to the computer bidder machine, rule 1 is appropriate when the computer is bidding during the segment 1. The computer machine should randomly select a bid time-interval from 2 seconds to 23 seconds. Rule 2 is suitable for segment 2. The computer machine should select a bid time-interval from 2 seconds to 9 seconds.

CHAPTER V

CONCLUSIONS

This research is the 26th case study of Reverse Auction Bidding in Texas A&M University. The research further analyzed the human being's behavior in a Reverse Auction Bidding. Based on the analysis of the data collected from previous RAB experiments, the research find there are two rules can be adopted for the computer bidder machine.

When the computer bidder machine is bidding during the first half of sections, which starts from 0 seconds to 450 seconds, the machine shall randomly select bid time intervals from2 seconds to 23 seconds.

When the computer bidder machine is bidding during the second half of sections, which starts from 450 seconds to 900 seconds, the machine shall select bid time intervals from 2 seconds to 9 seconds.

REFERENCES

Angelo, W. (2002). Reverse auctions and mold risks are worrying agc contractors. *Enr, 249*(14), 12.

Caniels, M. (2009). Do all suppliers dislike electronic reverse auctions? *Journal of Purchasing and Supply Management, 15*(1), 12-23. doi:10.1016/j.pursup.2008.10.003

Chaudhari, S.*Owner's interference in reverse auction bidding to skew a free market*

Daly, S. (2005). Reverse auctions for relationship marketers. *Industrial Marketing Management, 34*(2), 157-166. doi:10.1016/j.indmarman.2004.07.013

Demirbas, A. (2005). Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues. *Progress in Energy and Combustion Science, 31*(2), 171-192.

Dutch UMTS-auction ifo Institute for Economic Research.

Edelman, B. (2007). Internet advertising and the generalized second-price auction: Selling billions of dollars worth of keywords. *The American Economic Review, 97*(1), 242-259. doi:10.1257/aer.97.1.242

Fischbach, A. (2005). Bidders beware: The ins and outs of reverse auctions. *Ec&m, 104*(2), 14-C18.

Guhya, D.*Reverse auction bidding a statistical review of the first case study*

Gupta, A. K. (2010). *Studying the Reverse Auction Bidding Game for the Role Variants of Guardians in the Facilities Management Industry,*

Hahn, W. (2009). The winner's curse and optimal auction bidding strategies. *The Graziadio Business Report, 12*(2)

Hasbrouck, J. (2013). Low-latency trading. *Journal of Financial Markets, 16*(4), 646-679. doi:10.1016/j.finmar.2013.05.003

Jap, S. (2007). The impact of online reverse auction design on buyer-supplier relationships. *Journal of Marketing, 71*(1), 146-159. doi:10.1509/jmkg.71.1.146

Kingsley-Hughes, A., Kingsley-Hughes, K., & Read, D. (2004). *VBScript programmer's reference*. John Wiley & Sons.

Krishna, V. (2009). *Auction theory*. Academic press.

Manahov, V. (2014). Does high frequency trading affect technical analysis and market efficiency? and if so, how? *Journal of International Financial Markets, Institutions & Money, 28*, 131-157. doi:10.1016/j.intfin.2013.11.002

Manoochehri, G., & Lindsy, C. (2008). Reverse auctions: Benefits, challenges, and best practices. *California Journal of Operations Management*, *6*(1), 123-130.

Mcafee, R. P. (1987). Auctions and bidding. *Journal of Economic Literature, 25*(2), 699-738.

Metzgar, C. (2008). A literature review on reaction time. *Professional Safety, 53*(1), 20-21.

Patten, R. W. (1970). Tatworth candle auction. *Folklore, 81*, 132-35. doi:10.1080/0015587X.1970.9716671

Pham, L. (2015). Multi-attribute online reverse auctions: Recent research trends. *European Journal of Operational Research, 242*(1), 1-9. doi:10.1016/j.ejor.2014.08.043

S. Wu, I. (2014). Maximum impact for minimum subsidy: Reverse auctions for universal access in chile and india. *Info, 16*(5), 46-58.

Shalev, M. (2010). Electronic reverse auctions and the public sector: Factors of success. *Journal of Public Procurement, 10*(3), 428-452.

Smeltzer, L. (2003). Electronic reverse auctions: Promises, risks and conditions for success. *Industrial Marketing Management, 32*(6), 481-488. doi:10.1016/S0019-8501(02)00257-2

Srinath, T. R., Kella, S., & Jenamani, M. (2011, February). A New Secure Protocol for Multi-attribute Multi-round E-reverse Auction Using Online Trusted Third Party. In *Emerging Applications of Information Technology (EAIT), 2011 Second International Conference on* (pp. 149-152). IEEE.

Standing, S. (2013). How organizing visions influence the adoption and use of reverse auctions. *Electronic Commerce Research, 13*(4), 493-511. doi:10.1007/s10660-013-9133-0

Van Vleet II, R. G. (2004). *Reverse auction bidding: An analysis of a case study* (Doctoral dissertation, Texas A&M University).

Varian, H. (2007). Position auctions. *International Journal of Industrial Organization, 25*(6), 1163-1178. doi:10.1016/j.ijindorg.2006.10.002

Vickrey, W. (1961). Counterspeculation, auctions, and competitive sealed tenders. *The Journal of Finance, 16*(1), 8-37. doi:10.1111/j.1540-6261.1961.tb02789.x

Wellington, V. (2006). [SQL Database Development for Reverse Auction Bidding Site at TAMU].

Yuan, S.*Reverse auction bidding - bid arrivals analysis*

APPENDIX A

SINGLE SEGMENT DATA ANALYSIS

The following figures are the results of linear regression analysis of case study 9 section 2, section 3, section 4, section 5 and section 6.

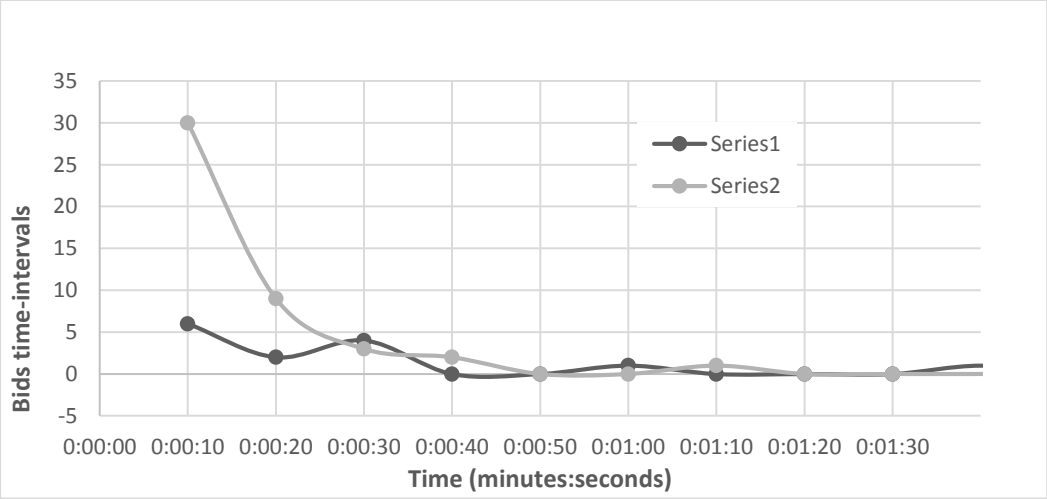


Figure 28 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 2

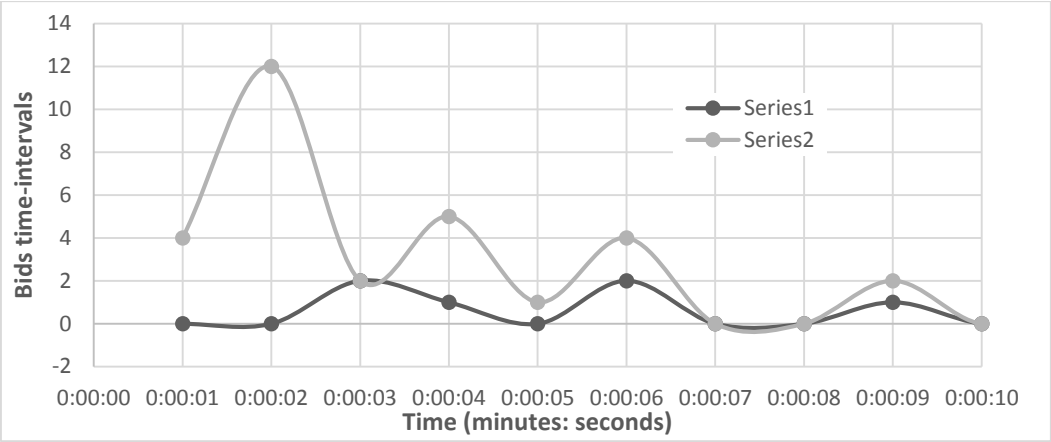


Figure 29 1 seconds Bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 2

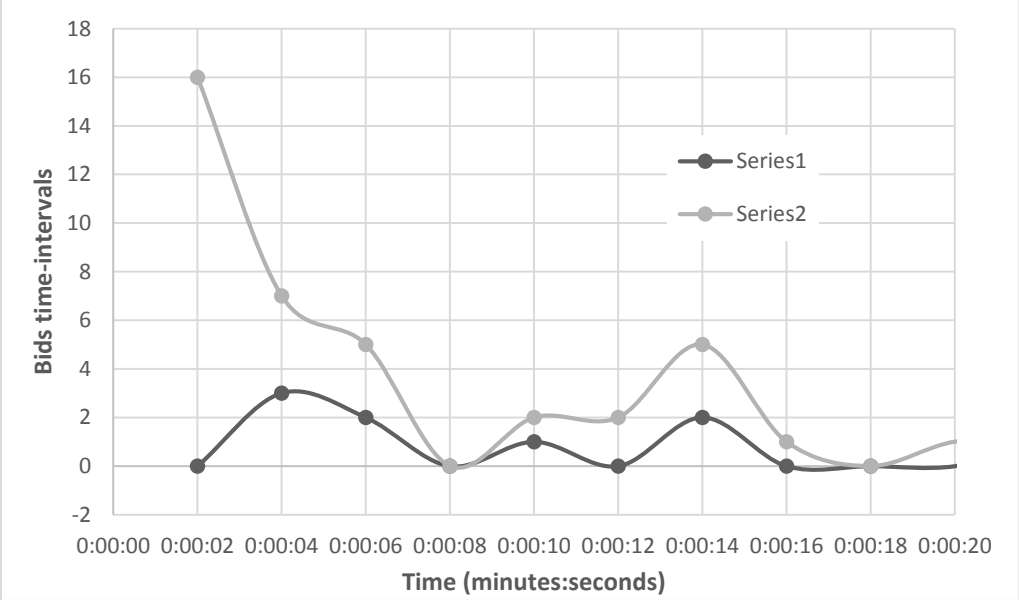


Figure 30 2 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 2

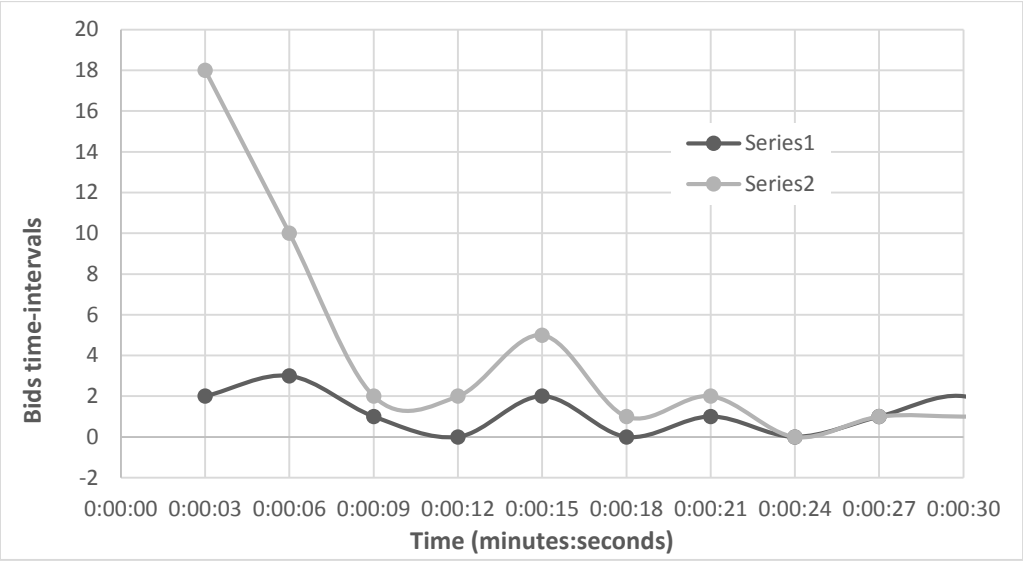


Figure 31 3 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 2

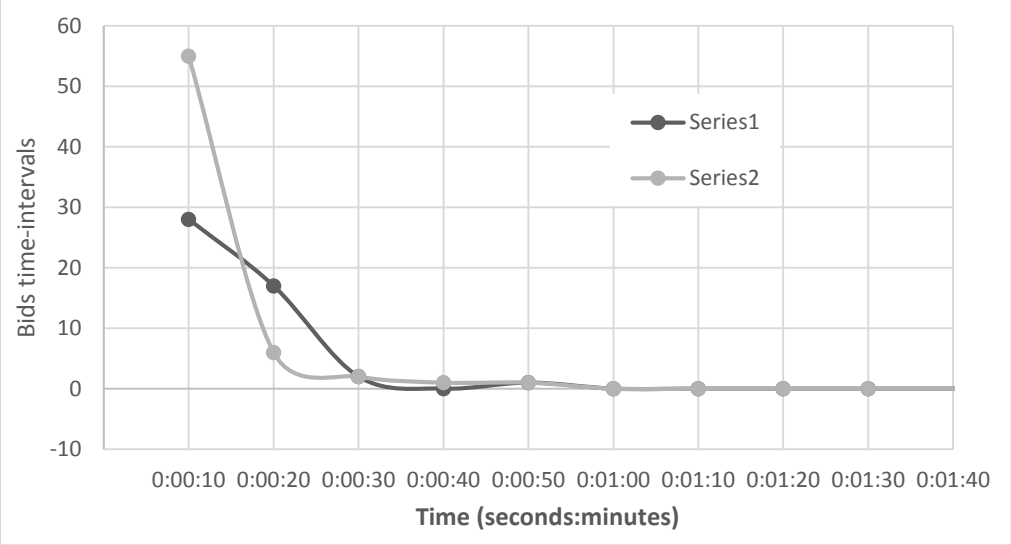


Figure 32 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 3

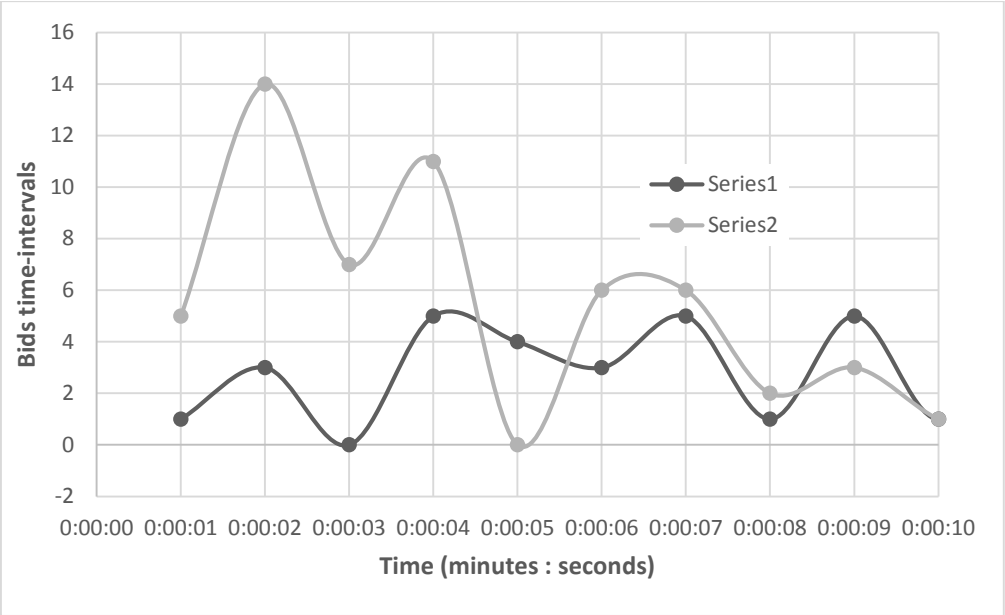


Figure 33 1 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 3

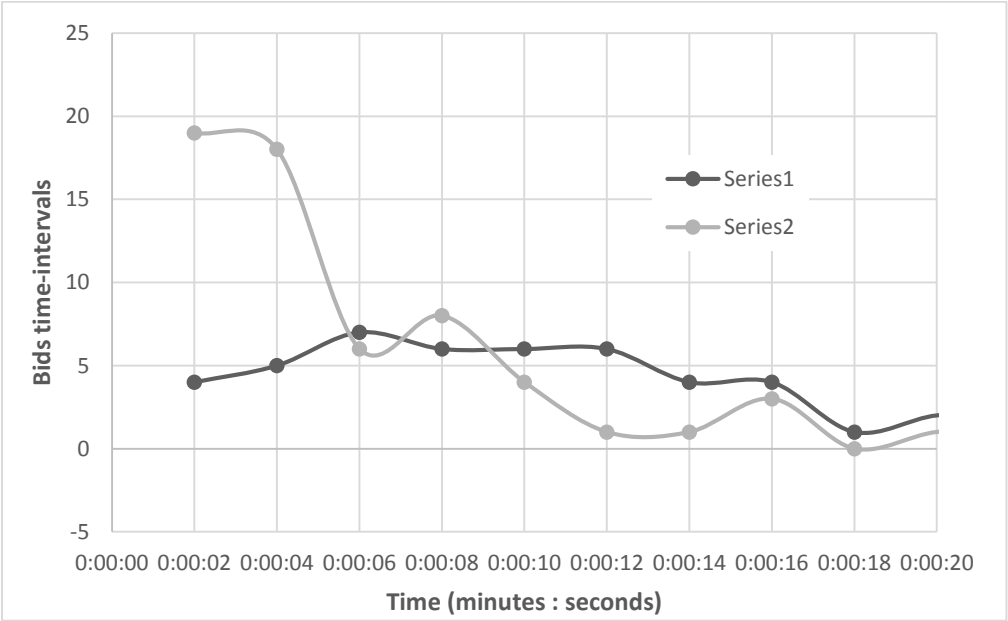


Figure 34 2 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 3

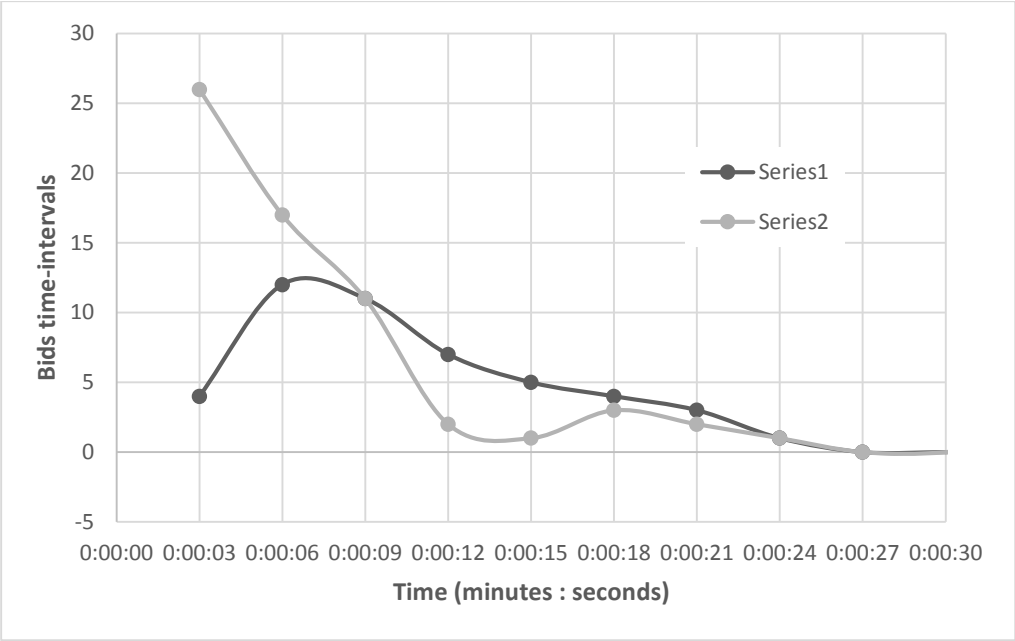


Figure 35 3 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 3

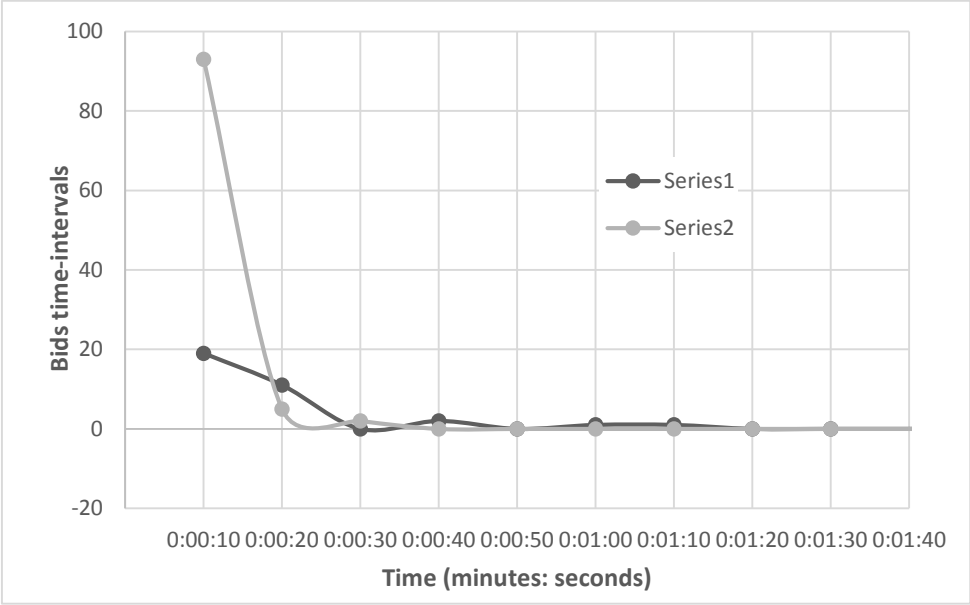


Figure 36 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 4

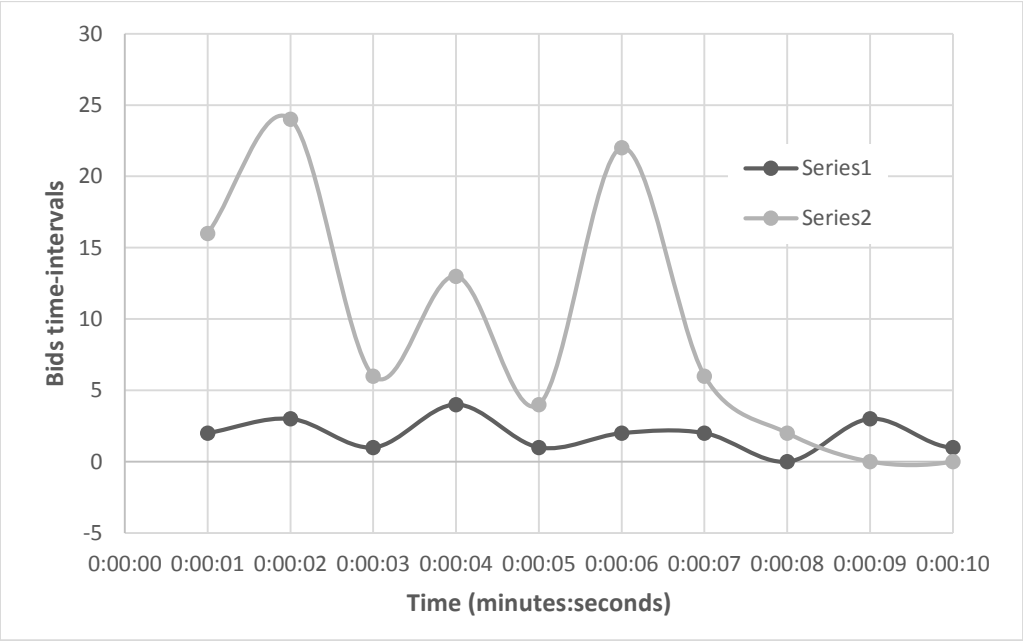


Figure 37 1 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 4

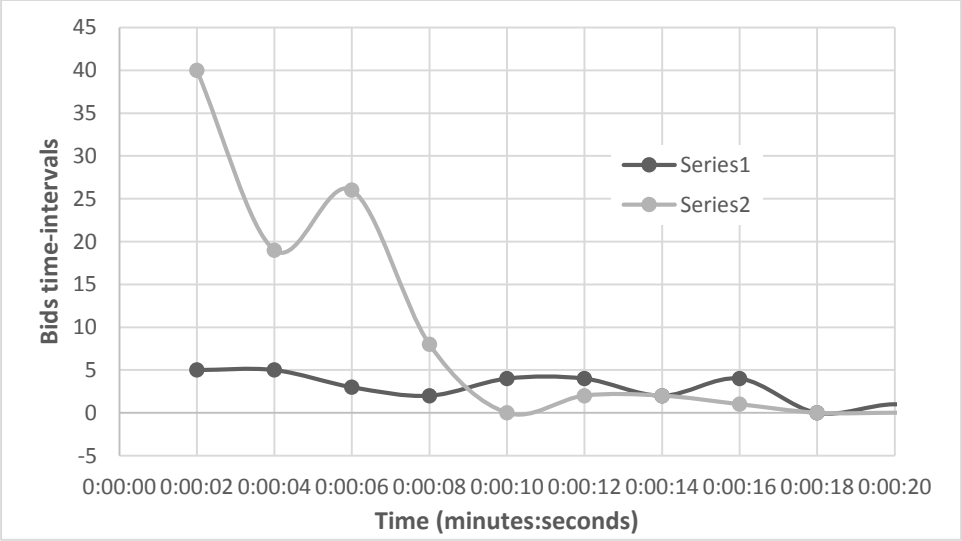


Figure 38 2 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 4

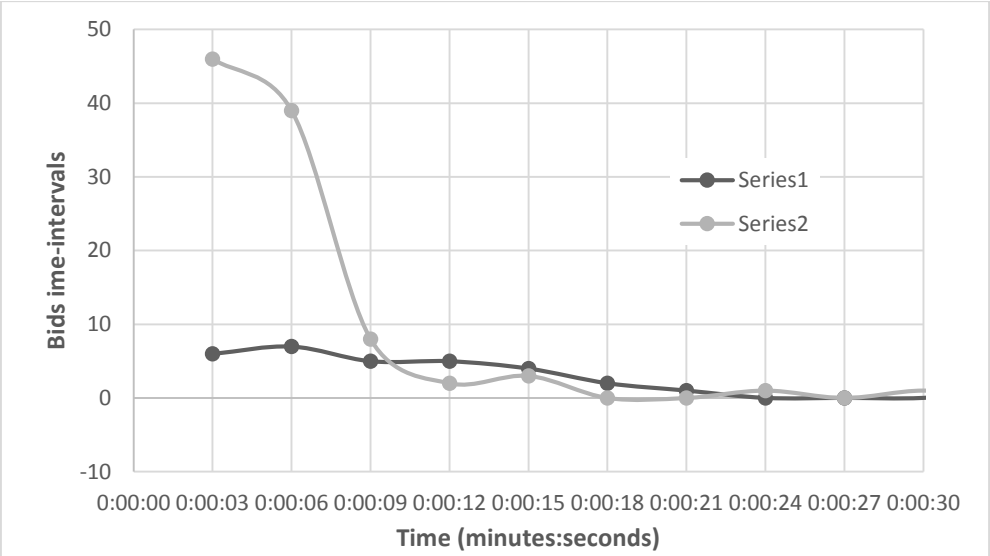


Figure 39 3 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 4

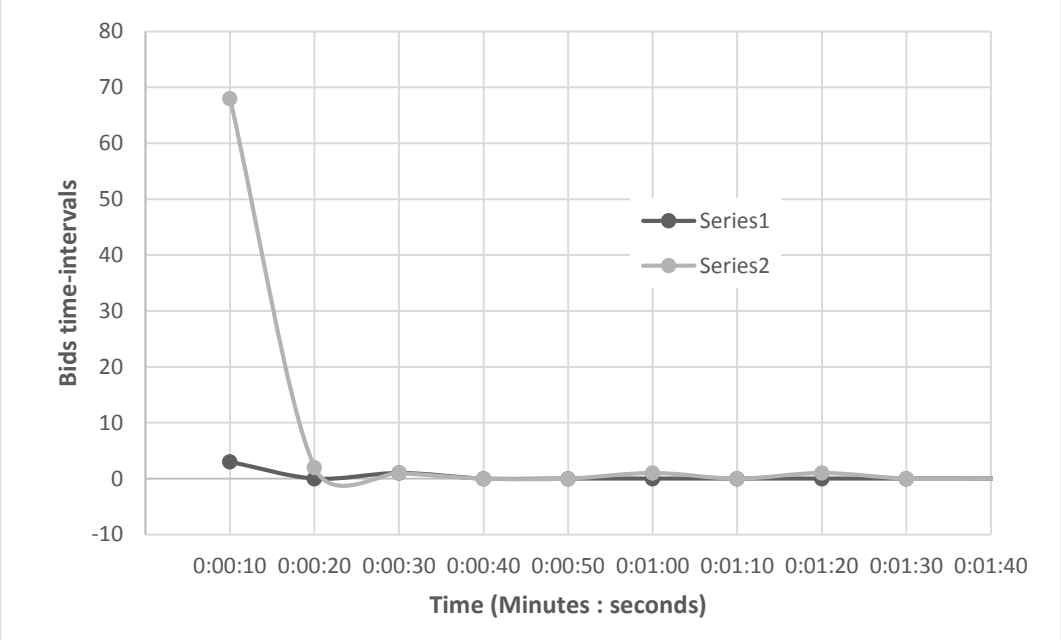


Figure 40 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 5

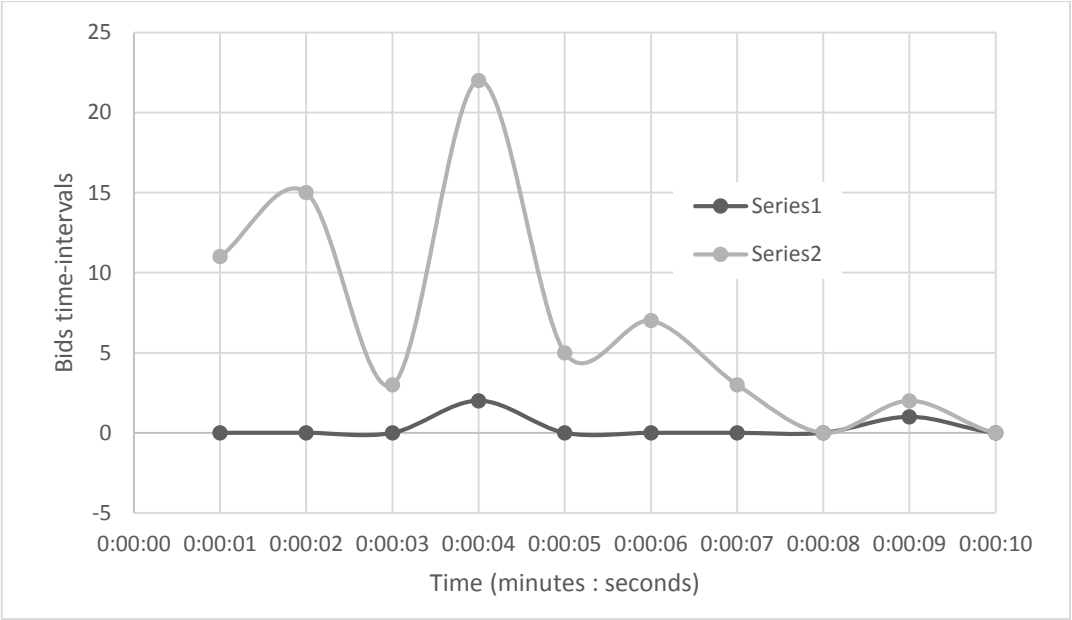


Figure 41 1 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 5

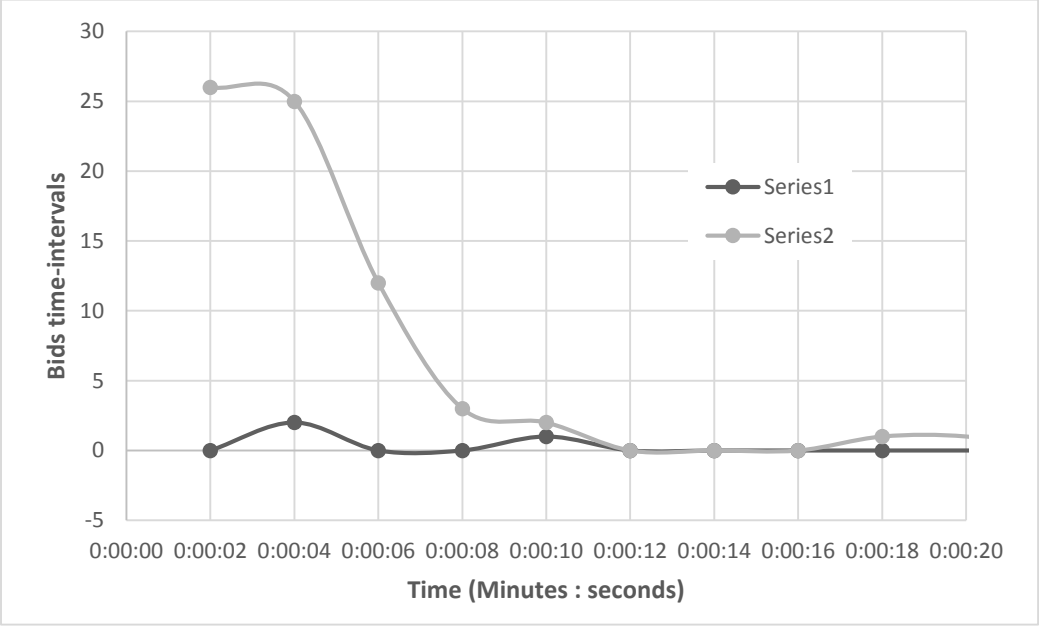


Figure 42 2 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 5

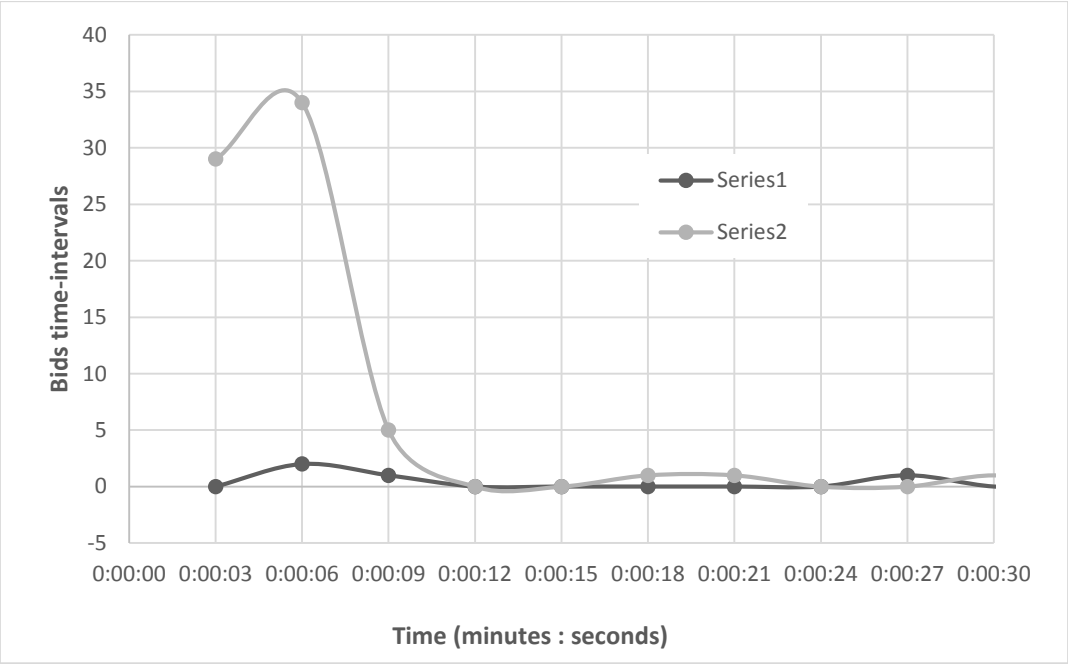


Figure 43 3 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 5

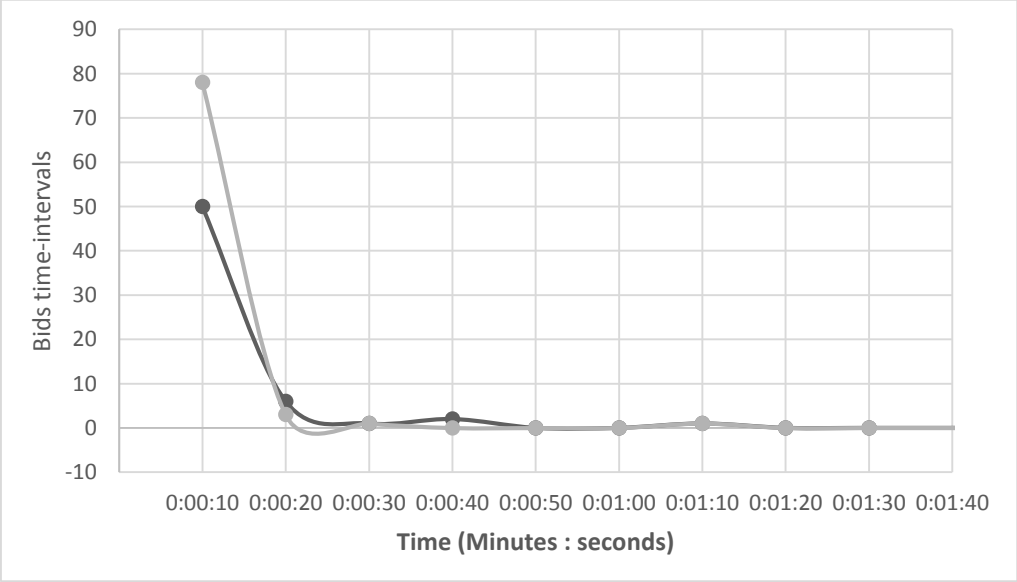
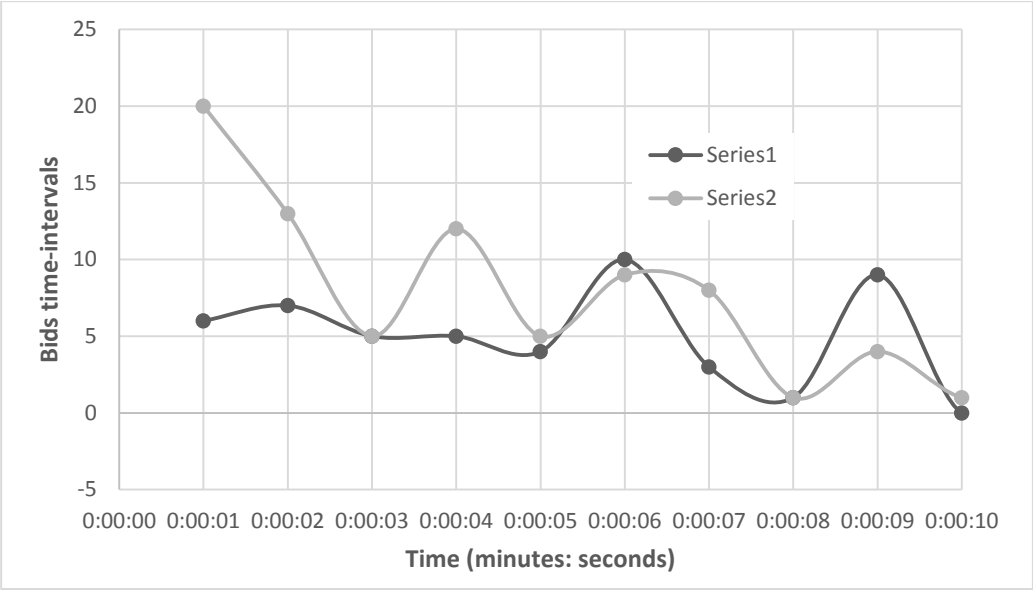


Figure 44 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 6



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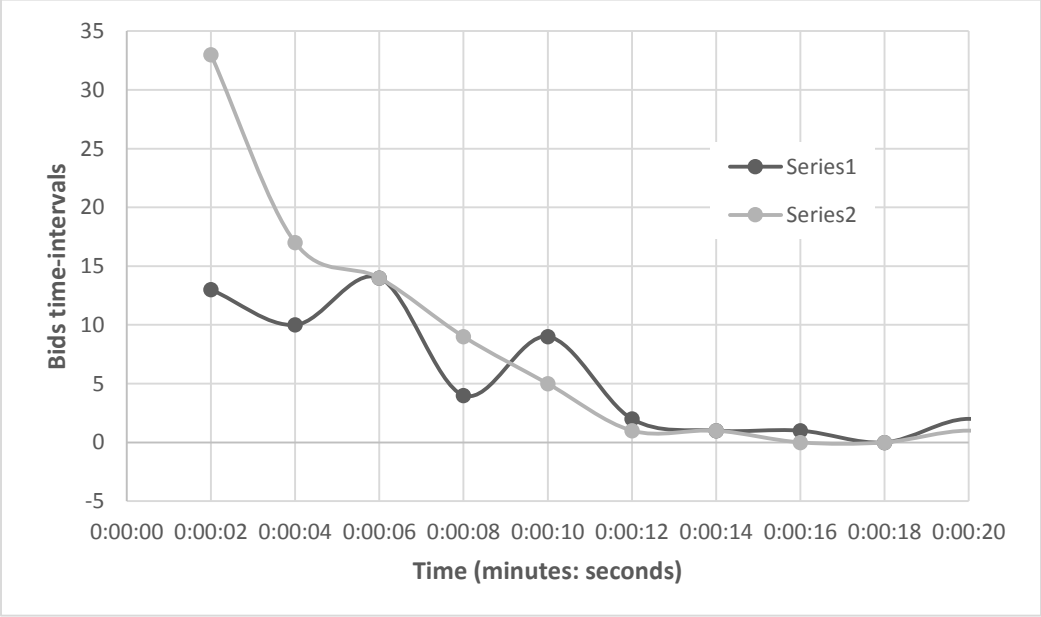

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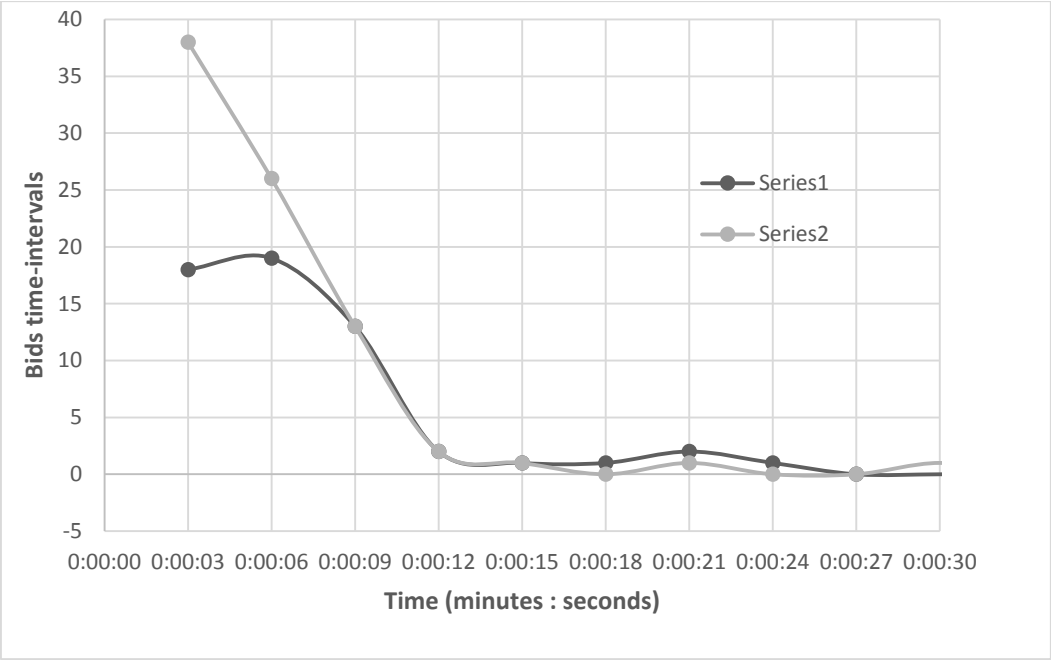

Figure 47 10 seconds bids Time-intervals comparison of segment 1 and segment 2 of case study 9 section 6